# SEP Evaluation 2010-2018

# Applied Physics department

# TU Eindhoven

# Content

# 1. Introduction

## 1.1 Scope of the review

This document reports on the results of an evaluation of the Applied Physics department of the Eindhoven University of Technology (TU/e) in accordance with the Standard Evaluation Protocol (SEP) 2015-2021 defined by the KNAW, VSNU and NWO. The review was performed by an evaluation panel appointed on November 5th, 2018 by the Rector Magnificus of the TU/e, and is based both on a self-assessment by the department, as well as a site visit that was conducted from December 11$^{th}$ – 13$^{th}$, 2018. During this site visit, further documentation was provided to the panel upon request, in particular in relation to the department´s past performance and the department´s positioning in relation to the Sector plan.

In accordance with the SEP, the panel assessed the research quality, the relevance to society and the viability of the Physics department, as well as the quality of its PhD program, and its measures to ensure research integrity and diversity. In doing so, the panel considered both the past performance of the department (within the period 2010-2018), as well as the strategy for the future defined by the department.

## 1.2 Members of the evaluation panel

The evaluation panel consisted of the following members:

- Prof. Dr. Anna Balazs, *Department of Chemical & Petroleum Engineering, University of Pittsburgh, USA*
- Prof. Dr. Jonathan Finley, *Walter Schottky Institute and Physics Department, Technische Universität München, DE*
- Prof. Dr. Niek van Hulst, *ICFO – The Institute of Photonic Sciences, Barcelona, SP*
- Prof. Dr. Eckart Meiburg, *Department of Mechanical Engineering, University of California at Santa Barbara, USA*
- Prof. Dr. Antoine Rousseau, *Laboratoire de Physique des Plasmas, Ecole Polytechnique, Palaiseau, FR*
- Prof. Dr. Marc Vrakking, Chair, *Max Born Institut für Nichtlineare Optik und Kurzzeit-Spektroskopie, Berlin, DE*
- Prof. Dr. Howard Wilson, *Department of Physics, University of York, UK*

## 1.3 Description of the research unit

The Applied Physics department of the TU/e views its mission as making contributions to physics and society by means of the education of students, by doing research and by valorizing the knowledge gained in its research. All three of these aspects are strongly influenced by the unique industrial eco-system that the TU/e is surrounded by, which has a high demand for both the human capital and the research output produced by the department.

The department encompasses twelve large research groups, each containing one or more full professors, as well as a number of associate and/or assistant professors. The research groups

represent key organizational units within the department, and provide continuity within chosen research themes, as well as opportunities for sharing of infrastructure and short-term financial risks.

The research groups are clustered within three disciplines ("clusters"), namely (i) FBS - Fluids, Bio and Soft Matter, (ii) PB - Plasmas and Beams and (iii) NQP -Nano, Quantum and Photonics. The clusters

| **Research Groups of the department and Research Centers and Institutes managed by the department + their distribution over disciplines and valorization themes.** | **Research** | | | **Valorization** | | | |
|---|---|---|---|---|---|---|---|
| | Fluids, Bio and Soft Matter (FBS) | Plasmas and Beams (PB) | Nano, Quantum and Photonics (NQP) | Renewable Energy (RE) | Smart Materials and Processes (SMP) | High Tech Systems (HTS) | Engineering Health (EH) |
| **Research Groups** | | | | | | | |
| Molecular Biosensing for Medical Diagnostics (MBx) | ■ | | ■ | | | ■ | ■ |
| Theory of Polymers and Soft Matter (TPS) | ■ | | | ■ | ■ | ■ | ■ |
| Transport in Permeable Media (TPM) | ■ | | | ■ | ■ | | |
| Turbulence and Vortex Dynamics (WDY) | ■ | | | ■ | ■ | ■ | ■ |
| Coherence and Quantum Technology (CQT) | | ■ | ■ | | | ■ | |
| Elementary Processes in Gas Discharges (EPG) | | ■ | | | ■ | ■ | ■ |
| Plasma and Materials Processing (PMP) | | ■ | ■ | ■ | ■ | ■ | |
| Science and Technology of Nuclear Fusion (FUSION) | | ■ | | | ■ | ■ | |
| Advanced Nanomaterials and Devices (AND) | | | ■ | ■ | | ■ | |
| Molecular Materials and Nanosystems (M2N) | | | ■ | ■ | ■ | | |
| Photonics and Semiconductor Nanophysics (PSN) | | | ■ | ■ | | ■ | |
| Physics of Nanostructures (FNA) | | | ■ | ■ | | | ■ |
| **Research Centers and Institutes** | | | | | | | |
| Center for Computational Energy Research (CCER) | ■ | ■ | ■ | | ■ | | |
| Center for Quantum Materials and Technology (QT/e) | | ■ | ■ | ■ | | | |
| Institute for Photonic Integration (IPI) | | | ■ | | | ■ | |
| School of Medical Physics and Engineering (SMPE/e) | | | | | | | ■ |

*Figure 1: Placement of the individual research groups and research centers and the institutes managed by the department within the three research disciplines and valorization themes (adapted from Figure on p. 11 of the self-assessment). Please note that MBx is discussed in Section 2.2.1 on the FBS cluster, while CQT and PMP are discussed in Section 2.2.2 on the PB cluster. These three research groups are also part of the NQP cluster*

provide a natural context for interdisciplinary research collaborations, and play a vital role in the definition of future research themes within the department. Several research groups (i.e. MBx, CQT and PMP) contribute to more than one discipline. In addition to the research groups and the three disciplines, the department manages a number of institutes and research centers that are operated jointly with other departments within the TU/e or with external partners. An overview of the research groups, their contribution to the three research disciplines and the research centers and institutes managed by the department is given in Figure 1, along with their connection to the 4 valorization themes that the department has identified.

Recently the department has undergone a large-scale reorganization, which was made necessary by significant financial problems that had accumulated in previous years. The reorganization resulted in cost savings within the structural budget totaling approximately 1 M€/year, which were realized in particular by streamlining the staff and optimizing the ratio between research and support staff. The reorganization furthermore led to a far-reaching redefinition of the research strategy (including the establishment of the aforementioned research disciplines, see Figure 1). The reorganization has only recently been completed, and therefore the redefinition of the research strategy has not been completed and is an ongoing process. Detailed discussions about research directions that will be strengthened and/or initiated in the future will only be completed in the near future, in connection with the department´s application for the Sector plan, and the establishment of six cross-disciplinary Research Themes within the TU/e. The department hopes to attract funding for the support of 4-6 new staff positions from the Sector plan, and plans to use these positions for the establishment of novel links between the three research disciplines.

The department´s detailed plans for its application within the Sector plan, and, accordingly, its vision for the further development of its research agenda, were not yet contained in the self-assessment document that was provided to the panel prior to the site visit. The current status of the preparations for the Sector plan application, and – in particular – the department´s current ideas for the establishment of up to 8 new staff positions, were communicated to the panel during the site visit as part of material that was discussed during a series of meetings with representatives of the three research clusters (FBS, PB and NQP) on the first day of the site visit, and – in particular – during a meeting with the dean of the department and one representative from each research cluster on the second day of the visit. In Sections 2.2 and 3.1 of this report, the panel will comment on the ideas that were presented during these meetings.

# 2. Assessment of the research unit

## 2.1 Description of the research unit's strategy and targets

The vision of the department for the next years focuses on three key elements, namely **People**, research **Focus** and **Valorization**.

**People**

In line with policies that were recently introduced at the TU/e, the department is in the process of implementing a new structure where all researchers have the position of Principal Investigator. In contrast with the former situation, where full professors were in a position of authority with respect to associate professors, assistant professors and tenure-track researchers, the department is implementing a new model where scientists at diverse career stages are independent and thus have optimal opportunities for realizing their own, personal research vision. A special role is played in this respect by tenure-track researchers. The department strives towards a situation where young researchers with a high potential for reaching the level of a full professorship are attracted into tenure-track positions, the clearly stated goal being that these appointments lead to a permanent position in the majority of cases. To this end, the department emphasizes the advantage of placing the tenure-track researchers in the supportive environment of a research group (i.e. one of the twelve research groups indicated in Figure 1), where there are opportunities for sharing of sophisticated research infrastructure, in many cases significantly exceeding the cost and complexity that would otherwise be within reach of a starting research team, as well as opportunities for mentoring by more senior faculty.

**Focus**

As a major step towards the creation of research focus, the department has recently adopted a new organizational structure, where all research groups are now part of one or more research disciplines, also called "clusters", namely (i) FBS - Fluids, Bio and Soft Matter, (ii) PB - Plasmas and Beams and (iii) NQP - Nano, Quantum and Photonics (see Figure 1). This new grouping of the – for the most part – existing research groups has created a structure where, both physically and organizationally, research groups find themselves in the vicinity of the other research groups that they most intensively collaborate with, or would be most likely to. This change in the organizational structure is accompanied by the introduction of several novel elements within the governance of the department, such as the introduction of a Scientific Advisory Committee, consisting of one member from each new scientific discipline. The purpose of the Scientific Advisory Committee is to advise the Faculty Board on issues of research strategy and the merits (both in terms of research and valorization potential) of new proposals for permanent positions.

**Valorization**

As the third element in the department´s research vision, valorization is at the heart of a significant fraction of the department´s research activities. Valorization is both a natural consequence of the industrial eco-system in and around Eindhoven, which contains many high-tech companies that are keen on benefitting from the expertise and research opportunities that are available in the department, as well as an element that is deeply engrained in the TU/e as whole, and a feature by

which the university and the department distinguish themselves from other institutions in the Netherlands. The department has embraced four main valorization themes “Smart Materials and Processes”, “Renewable Energy” “High Tech Systems” and “Engineering Health” (see Figure 1 on page 4) that are directly linked to the Cross-disciplinary Research Themes defined at the TU/e level.

## 2.2 Qualitative and quantitative assessment (1. research quality; 2. relevance to society; 3. viability)

The panel has evaluated the strategy of the department along the same criteria defined by the department, i.e. in terms of **People**, research **Focus** and **Valorization**. We will comment on the strategy in general terms to the extent that it pertains to the department as a whole, before commenting on more detailed aspects of the strategy pertaining to the three research clusters. Furthermore, in line with the SEP guidelines, these comments are translated into an assessment of the research quality of the department, the department´s relevance to society and the department´s viability.

**People**

With respect to the development of people, the panel applauds the decision to introduce a new structure where all researchers have the position of Principal Investigator. The panel considers that the scientific staff is the biggest capital that a research institution possesses, and hence the attraction and nurturing of developing scientific careers is a key element in any successful scientific strategy. The panel believes that under the inspired leadership of its dean, the department has adopted a highly credible approach towards hiring and career development of younger faculty, and considers that the attraction of highly-talented (in particular, female) tenure-track researchers should remain a top priority in the years to come. While recognizing the largely very positive feedback that it received from the tenure-track researchers that were interviewed, the panel notes that it should be the ambition of the department to increase the uniformity across groups of the opportunities that junior faculty receive in terms of mentoring by senior faculty, in terms of publishing of research results without co-authorship of more senior faculty (in the absence of significant scientific contributions of said researchers), and in terms of the promotion of an independent research profile by means of a web presence. The panel appreciates that for many of the tenure track researchers the availability of a cohesive in-house environment provides attractive opportunities for extensive collaboration, but at the same time would like to stimulate external collaborations, which are vital for the development of an independent scientific career beyond the initial stage. Finally, the panel considers it extremely positive and important that in the future the now-healthy financial status of the department will permit offering more attractive start-up packages (even retro-actively).

**Focus**

With regard to the question of research focus, the establishment of the new research disciplines (i) FBS - Fluids, Bio and Soft Matter, (ii) PB - Plasmas and Beams and (iii) NQP - Nano, Quantum and Photonics, and the introduction of novel advisory structures such as the Scientific Advisory Committee, significantly improves the department´s ability to respond to novel challenges and novel opportunities such as the current Sector plan and the TU/e-internal definition of Cross-disciplinary Research Themes. With regards to these novel opportunities, it appears evident that in the future

the department will face several crucial strategic choices, which will have a long-lasting impact. For instance, the new positions that the department hopes to gain via the Sector plan are, on the one hand, a mechanism to further develop and strengthen individual existing research directions, but, on the other hand, are also a mechanism that may be used to develop novel “out of the box” research directions, for example at an inter-disciplinary interface between two, so far disjoint research activities. During its site visit the panel has taken note, with interest, of the department´s current ideas on these important strategic questions, and the panel has convinced itself that the department is on track towards answering these questions in a convincing manner. A more detailed discussion of the implications of the Sector plan and the TU/e-internal Cross-disciplinary Research Themes will be given below, in a discussion of the individual research disciplines.

**Valorization**

The panel clearly recognizes the added value that is created by the department´s knowledge and technology transfer and the numerous joint research activities with external partners – both within the university and in connection with high-tech industries in the direct vicinity of the university. Valorization of the research results achieved within the department builds on a decades-long tradition, which is so well established that meanwhile the department finds itself in the enviable and unique position that only modest efforts are needed to initiate new valorization activities, given that many of these activities nowadays occur in response to direct requests made by external partners. The panel expects that the recent reorganization, and the resulting streamlining and increased transparency of the department´s research structure, will in future only further enhance these valorization opportunities.

### 2.2.1 Research cluster: Fluids, Bio and Soft Matter

| **Research Groups** | |
|---|---|
| | |
| **Molecular Biosensing for Medical Diagnostics (MBx)** | |
| Menno Prins, full professor<br>Leo van IJzendoorn, associate professor<br>Arthur de Jong, assistant professor<br>Peter Zijlstra, assistant professor | MBx develops technologies to detect, study, and monitor biomolecules with single-molecule resolution based on the use of colloidal particles. Its mission is to be at the forefront of research and student training in this field. |
| **Theory of Polymers and Soft Matter (TPS)** | |
| Kees Storm (chair), full professor<br>Paul van der Schoot, associate professor<br>Wouter Ellenbroek, assistant professor<br>Alexey Lyulin, assistant professor<br>Liesbeth Janssen, assistant professor | TPS performs theoretical and simulation-based research into the physics of soft, biological, bio-mimetic and bio-inspired materials. Five coherent PI groups link physical concepts and foundations to application and design of new materials. |
| **Transport in Permeable Media (TPM)** | |
| Gerrit Kroesen, program leader<br>Leo Pel, associate professor<br>Henk Huinink, assistant professor<br>Olaf Adan, extraordinary professor | TPM aims to have a recognized scientific reputation in the international physics community concerning transport in permeable media, with a world-leading position in heat storage materials. The group positions itself in the field of curiosity driven/application-inspired research, combining experiment and modeling. Further, its aim is to consolidate its strength in the application of Nuclear Magnetic Resonance imaging tools in the field of porous media |
| **Turbulence and Vortex Dynamics (WDY)** | |
| Herman Clercx (chair), full professor<br>GertJan van Heijst, full professor<br>Federico Toschi, full professor<br>Anton Darhuber, full professor<br>Leon Kamp, associate professor<br>Rudie Kunnen, assistant professor<br>Jos Zeegers, assistant professor<br>Matias Duran Matute, assistant professor<br>Hanneke Gelderblom, assistant professor | WDY aims at being an internationally leading group in the fundamental understanding of small-scale transport processes in (geophysical) turbulence, environmental flows, statistical fluid mechanics (including complex fluids) and multiphase and multicomponent (turbulent) flows, and apply knowledge thereof in collaboration with external (industrial) partners. For this goal, we have established a coherent research program on fluid mechanics, turbulence, and computational physics supported by modern experimental infrastructure. |

**Overview**

The cluster Fluids, Bio and Soft Matter (FBS) consists of the groups Molecular Biosensing for Medical Diagnostics (MBx), Transport in Permeable Media (TPM), Theory of Polymers and Soft Matter (TPS), and Turbulence and Vortex Dynamics (WDY). MBx focuses on biosensing with single-molecule resolution using nanoparticles, with a view towards developing novel health monitoring technologies. TPM addresses the topics of transport and phase changes in complex permeable media, with the goal of developing novel materials for energy-related applications. TPS advances theoretical and simulation approaches of soft and biological materials in the context of the mechanobiology of cells and tissues, as well as functional soft materials. WDY focuses on complex fluids and flows, and specifically on turbulence and environmental fluid mechanics, multiphase flows and active matter, and micro- and nanohydrodynamics. Shared interests between the individual groups are found in the themes rheology of active biofluids, transport in multicomponent systems, and particle biosensors.

**Research quality**

The research quality of the cluster is uniformly outstanding, as evidenced by numerous high-profile publications in both disciplinary (e.g., Physical Review Letters, Nano Letters, Applied Energy) and broader journals (e.g., Nature, PNAS, Langmuir), as well as by citation data. The quality of the cluster's faculty is further highlighted by numerous prizes, awards and research society fellowships, as well as journal editorships.

The Molecular Biosensing for Medical Diagnostics group (MBx) conducts cutting-edge research that explores the use of nanoparticles in biosensing applications with single-molecule resolution. Its output in recent years in terms of high-profile research publications has been excellent, with first-rate contributions to the exploration of the mobility of nanoparticles, plasmonics and single-molecule fluorescence. The activities of the MBx research group hold great potential for deriving significant societal benefits in the medical field, which should also open up additional opportunities for valorization.

It is unique to have an excellent and significant number of scientists focused on the modelling of polymers and soft matter within the Theory of Polymers and Soft Matter (TPS) group. This is a very exciting and important area of research since polymers and soft matter play a vital role in areas ranging from energy to health care. Moreover, having predictive, robust models to guide experimental studies is critical to performing efficient and effective research. Notably, the group encompasses research in both theoretical modelling and computer simulations; hence both analytical theory and numerical approaches are covered. The areas of research performed by each group are complementary and thus, there exists synergy among members of the group. This type of collaborative atmosphere is excellent for training the next generation of polymer/soft matter engineers and scientists. Each of the researchers in the TPS group is very active in the polymer/soft matter community and there is a nice span of people at different stages of their careers that will help ensure the health and continuity of the cluster's activities. We just point out some of these individuals. The hire of Liesbeth Janssen helps broaden the depth of the department in biological physics and non-equilibrium behavior. The work and activities (e.g., conference organization) of Wouter Ellenbroek are receiving considerable attention. The work of Paul van der Schoot is highly recognized in the self-assembly and soft matter communities. The entire group seems well-guided

under the leadership of Prof. Storm. Overall, the research output of the group is excellent, with scientists working in cutting edge areas of active matter, non-equilibrium dynamics and biophysics.

The Transport in Permeable Media group (TPM) is relatively small in size, but nevertheless has a strong research impact, driven by novel applications associated with transport and storage in porous media. Exploration of the physical mechanisms underlying the storage of thermal energy in porous media represents a timely research topic, as is the influence of phase change on transport mechanisms in porous media. These lines of research appear to hold considerable potential for the valorization of the ongoing research activities. The unique facilities associated with the Darcy-lab furthermore open up significant opportunities for internal and external research collaborations.

Similarly, the Turbulence and Vortex Dynamics (WDY) group is internationally recognized for conducting leading-edge research in the areas of stratified and rotating flows of geophysical relevance, with important applications in environmental modelling related to the dynamics of the atmosphere and oceans. A further area of strength concerns the fields of multiphase flows and active matter, which are crucial for advancing the state of the art regarding a wide range of industrial and biological processes. Along similar lines, the area of nano- and microhydrodynamics is highly relevant to modern applications of fluid dynamics in the areas of medical applications. In summary, this group is well positioned to continue playing an internationally leading role in the exploration of fundamental transport processes.

**Relevance to society**

The target areas of 'BioEngineering Health' and 'Materials for Energy' have high societal relevance in light of an aging population accompanied by the health industry's growing share of the economy, as well as the energy-related challenges posed by climate change. These topics are well aligned with the PIs' areas of expertise and the general goals that are of importance to the University. Particularly notable is the development of a new Center (led by Prof. Dr. Vianney Koelman (CCER) and Prof. Dr. Peter Bobbert (M2N group)) aimed at developing software that will help researchers design materials for sustainable energy applications. There is also strong activity in the area of biomedical applications.

**Viability**

The alignment of the cluster's research directions with societal challenges and strategic funding opportunities such as the National Sector Plans, suggests that the cluster's prospects for long-term viability are bright. The cluster's hiring plans aim to further enhance collaborations between the individual research groups while addressing strategic novel research areas of strong current interests. Examples concern the application of concepts from fluid dynamics for the design of improved materials in the energy sector, for providing insight into the behavior of complex active fluids such as human crowds, and for developing an improved understanding of the interaction between soft biomaterials and adjacent fluid flows. Strategic hires in these areas are expected to further enhance the thematic coherence and research impact of the cluster.

Given the spread of career stages in the group and the areas of highly relevant research, the group is highly viable.

### 2.2.2 Research cluster: Plasmas and Beams

| **Research Groups** | |
|---|---|
| | |
| **Coherence and Quantum Technology (CQT)** | |
| Jom Luiten (chair), full professor<br>Ton van Leeuwen, full professor<br>Edgar Vredenbregt, associate professor<br>Servaas Kokkelmans, associate professor<br>Peter Mutsaers, assistant professor | The research of the group focuses on collective effects in dilute, strongly interacting systems of high phase-space density: ultra-cold atoms, quantum gases and plasmas, high-brightness electron, ion and atom beams. An essential aspect is light-matter interaction, both for manipulating particle phase-space distributions and for generating coherent radiation. In terms of applications the group aims at developing new sources of charged particles and X-rays for science, industry and medicine. |
| **Elementary Processes in Gas Discharges (EPG)** | |
| Gerrit Kroesen (chair), full professor<br>Jan van Dijk, associate professor<br>Job Beckers, assistant professor<br>Jürgen Kohlhepp, assistant professor<br>Sander Nijdam, assistant professor<br>Ana Sobota, assistant professor<br>Ute Ebert, extraordinary chair<br>Vadim Banine, extraordinary chair<br>Gerard van Rooij, extraordinary chair | EPG's mission is:<br>• To study in depth the physics of the plasma state of matter.<br>• To apply the acquired knowledge and scientific insight to demands from society and industry.<br>• To act as center of knowledge for plasma related issues for other disciplines. |
| **Plasma and Materials Processing (PMP)** | |
| Erwin Kessels (chair), full professor<br>Ageeth Bol, associate professor<br>Adriana Creatore, associate professor<br>Richard Engeln, associate professor<br>Adrie Mackus, assistant professor | PMP focuses on the advancement of the science and technology of plasma and materials processing, a research area which is in essence multidisciplinary and encompasses the research fields of plasma physics, surface science, and materials science. The scientific objective of the group is to obtain 'atomic' level understanding of the interaction of plasmas and reactive gases with materials. PMP aims at being an internationally leading and pioneering group in the field of atomic scale processing, for present-day and future applications in energy technologies, nanoelectronics and nanotechnology. |
| **Science and Technology of Nuclear Fusion (FUSION)** | |
| Niek Lopes Cardozo (chair), full professor<br>Roger Jaspers, associate professor<br>Josefine Proll, assistant professor<br>Guido Huijsmans, extraordinary chair | Primary mission: to attract, educate and train engineers with the interdisciplinary profile 'science and technology of nuclear fusion'. Research mission: in support of the educational mission the group maintains a broad research portfolio, ranging from materials science to theoretical physics. This is 'big science' research, performed in collaboration with inter alia ITER, the Max-Planck Institute IPP and other international research labs as well as TU/e groups and the on-site NWO-institute DIFFER. |

**Overview**

The Plasmas and Beams disciplinary cluster comprises four strong research groups: Coherence and Quantum Technology (CQT), Elementary Processes in Gas Discharges (EPG), Plasma and Materials Processing (PMP) and Science and Technology of Fusion (FUSION). Each has a clearly defined strategy, with a strong relevance to society that resonates well with the needs of regional industry and the DIFFER national institute for fundamental energy research. The national importance and international impact of the research across the cluster ensures each area has good income streams to remain viable, but there is some need to recruit staff in order to maintain this position in the future. Strategies are in place, as we discuss below.

**Research Quality**

The TU/e Applied Physics department is clearly a world reference in the field of plasma physics, with a strong international profile. Two groups work on the field on Non-Thermal Plasmas, namely Elementary Processes in Gas Discharges (EPG) and Plasma Material and Processing (PMP). These groups cover the fundamentals of plasma discharges and chemistry, and their applications. Within EPG, innovative experiments as well as models have been developed to address scientific questions arising from modern applications. Prominent recent works have been recently made in the field of transient discharge physics. An important area of the group's research, which is very topical internationally at present, is the behavior and properties of plasmas at complex surfaces (solid, liquids, porous media, tissue, etc.); fundamental research is well balanced with applications. Within PMP, remarkable achievements have been made to understand the interaction of plasmas with reactive surfaces at the atomic scale and to master the technique of atomic layer deposition. Atomic scale control is used for the generation of materials for a wide range of applications. The overall Non-Thermal Plasma research is highly multidisciplinary and of very high quality. The number of publications, their quality, and their impact are excellent. Besides high-level fundamental aspects, numerous applications are explored which have very high societal impact.

The Coherence and Quantum Technology (CQT) group performs high impact science in the area of quantum coherence in dilute, strongly-interacting many body systems. The group brings together expertise on atomic physics, plasma physics and accelerator physics and technology in a manner that is rather unique worldwide, and that permits the development of ground-breaking electron and ion acceleration concepts, with tremendous application potential in (time-resolved) electron microscopy and diffraction, focused ion beam milling and X-ray generation. The mix of theory and experimental capabilities is an important strength that underpins a range of frontier, basic science research – in areas such as ultra-cold atoms, quantum gases and plasmas – with high impact in the development of quantum simulators. A strength of the research is the close relationship with industry, with funding from companies such as Thermo Fisher and ASML, as well as with international research organizations such as CERN.

The research in fusion energy complements the program at DIFFER well. The work on diagnostic techniques provides access to international facilities, such as the W7-X stellarator in Germany and the KSTAR superconducting tokamak in South Korea. The research on W7-X also benefits from the expertise in turbulence modelling of a talented tenure-track appointment (Josephine Proll), who is rapidly establishing herself in this high impact area of fusion science. The JOREK code, for simulating fusion plasma instabilities and associated transport, is one of the international community standard

codes. The fusion research goes beyond plasmas, into the important area of materials for extreme environments, including the role of liquid metals. Moving further from plasmas, the research into the economic viability of fusion energy, and how to optimize its entrance into the market place is valuable – a university environment enables a rigorous, independent assessment.

Two joint conferences each year are valuable for creating opportunities to explore new research directions that exploit the synergies that exist across the plasma groups.

**Relevance to society**

Plasma science has many applications in industry, and the Research Unit at TU/e has a strong set of industrial partners that ensures its research has maximum impact. This includes companies and laboratories such as Philips, ASML, Thermo Fischer Scientific, VDL-ETG, DIFFER etc., some with part-time positions at TU/e to consolidate the links. In fusion, the Research Unit works in close partnership with the national program at DIFFER to ensure a complementary research program which informs its very effective fusion education program and provides an environment for knowledge transfer between fusion and other disciplines.

Non-Thermal Plasmas are strongly connected to industrial applications in general. In particular, the Applied Physics department of TU/e has a long tradition of collaborations with industry due to many companies active in research and innovation, in or near Eindhoven. Examples include energy technologies such as Photovoltaics and $CO_2$ conversion, as well as nano-electronics and nanotechnology. Collaboration with the DIFFER organization is a great strength for developing relevant and applicable research programs across the field of energy.

**Viability**

While the groups are all financially viable, with good funding streams and good opportunities for high impact research outputs, there is a need to create new staff positions in order to secure the long term prospects for the cluster. The senior staff working in the area of Coherence and Quantum Technology (CQT) is due to retire within a year of each other within the next decade. The Cluster is aware of the threat that this poses, and has a solid recruitment strategy in place in order to secure the best in the field and ensure a smooth transition from the present generation to the next. The fusion program also has a strategy to further strengthen its position. The proposal to recruit in the area of simulation of plasma wall interaction aligns well with the national program on MAGNUM-PSI at DIFFER, and the strategy to create part-time appointments of leading, early career DIFFER staff will ensure a sustainable program well into the future that further cements the relationship with DIFFER. The panel supports the proposal to recruit into the area of elementary processes that underpin the dynamics of plasmas (cross sections, transport, etc.); however, it is important that the high impact scientific opportunities are identified, as well as potential funding routes.

### 2.2.3 Research cluster: Nano, Quantum and Photonics

| **Research Groups*** | |
|---|---|
| | |
| **Advanced Nanomaterials and Devices (AND)** | |
| E.P.A.M. Bakkers, full professor<br>J.E.M. Haverkort, associate professor | The groups is driven by a fascination of new properties of materials at the nanoscale. These properties are radically changed by their size, crystal structure or by surface states. We focus on the growth of new material systems and investigate the structural, optical, thermal, and electronic properties and their applications. We have chosen to work with nanowires since these offer an unprecedented level of flexibility and control. |
| **Molecular Materials and Nanosystems (M2N)** | |
| René Janssen (chair), full professor<br>Reinder Coehoorn, full professor<br>Peter Bobbert, associate professor<br>Kees Flipse, associate professor<br>Stefan Meskers, associate professor<br>Gerwin Gelinck, extraordinary professor | M2N aims at being an internationally leading group in the discipline of functional molecular materials and their optoelectronic devices. For this goal a coherent scientific research program has been established on the chemistry, physics, and materials science of functional nanostructured molecular, polymer and hybrid materials, and nanosystems that may find application in photonic and electronic devices. |
| **Photonics and Semiconductor Nanophysics (PSN)** | |
| A. Fiore (chair), full professor<br>J. Gomez-Rivas, full professor<br>P.M. Koenraad, full professor<br>R.W. van der Heijden, associate professor<br>A. González Curto, assistant professor<br>A. Silov, assistant professor<br>M.E. Flatté, extraordinary professor<br>E. Verhagen, extraordinary professor | PSN investigates the novel physics and applications emerging from the interaction of light with nanoscale matter. Atomic-scale characterization, advanced nanofabrication methods, and optical spectroscopy are combined in order to understand the structural, electronic and optical properties of nanostructures and this knowledge is further applied to investigate novel photonic structures for optical communications, energy harvesting and sensing. |
| **Physics of Nanostructures (FNA)** | |
| Bert Koopmans, full professor<br>Henk Swagten, full professor<br>Reinoud Lavrijsen, assistant professor<br><br>Rembert Duine, extraordinary professor | FNA strives to internationally excel in device-oriented nanoscience and technology, exploring physical phenomena at the nanometer scale by engineering the spin-dependent and magnetic properties. Focus is on novel concepts that are of potential relevance for future nanoelectronics. The group aims to create synergy by close connections with (industrial) users and research institutes, and maintains an internationally competitive infrastructure for thin film research. |

** Please note that the Research Groups "Molecular Biosensing for Medical Diagnostics" (MBx), "Coherence and Quantum Technology" (CQT) and "Plasma and Materials Processing (PMP)" also are part of this cluster. MBx is described in section 2.2.1, whereas CQT and PMP are described in section 2.2.2.*

**Overview**

The Nano and Quantum Photonics disciplinary cluster comprises four very strong research groups with scientific foci that span the range from fundamental studies of novel physical, photonic, electronic and magnetic properties of nano- and molecular-scale materials to applied nanoscience and novel devices. For example, the Advanced Nanomaterials and Devices (AND) group focuses on the synthesis, microscopy and spectroscopic characterization of nanoscale group-III arsenide and phosphide nanowires (NWs). Their research has both fundamental and applied character, linking to emerging potential applications in nanoscale opto-electronics, photo-voltaics with prototype systems of relevance for quantum information science and technology. The Molecular Materials and Nanosystems (M2N) group explores functional molecular materials and their use in novel opto-electronic and photo-chemical devices. The Photonics and Semiconductor Nanophysics (PSN) group explores GaAs based quantum photonic nanosystems, as well as organic emitters and atomically thin 2D-van der Waals materials and the Physics of Nanostructures (FNA) group focuses on highly relevant device orientated nanoscience that exploits spin-dependent and magnetic properties to realize nanodevices such as (magnetic) data storage, memory, logic and sensor applications. The national importance and international impact of the research across the cluster ensures each area has good income streams to remain viable into the future, but there is some need to recruit staff in order to maintain this position in the future. Here, well thought out strategies are in place, as we discuss below.

**Research Quality**

The evaluation committee found the scientific themes addressed in this cluster to be of a very high scientific quality, with some aspects ranked as being very good and others clearly having a world leading character. For example, the AND group synthesizes, grows and patterns materials that have unique qualities, providing much scope for highly novel foundational studies of quantum phenomena (e.g. *Quantum transport in materials with strong SO-interaction / Majorana Physics*, *Topological States of Matter in Quantum Transport*, *optical spin-Hall physics*, *novel optical processes in hexagonal SiGe* and *photovoltaics using ordered NWs* to mention only a selection). The M2N group explores functional molecular materials and their use in novel opto-electronic and photo-chemical devices. Here, the evaluation committee recognized their key role linking the departments of Applied Physics, Chemical Engineering and Chemistry at the TU/e. They establish structure-property-function relationships at a mean-field level by combining an impressive range of analytical, microscopic and spectroscopic methods and complement experimental studies with numerical modelling. The PSN group explores GaAs based quantum photonic nanosystems, as well as organic emitters and atomically thin 2D-van der Waals materials. Here, a specific emphasis is placed on nanofabricated and integrated nanophotonic quantum sources, circuits and detectors having a measurable photonic response at the quantum limit, topics that are clearly of strong relevance for photonic-based quantum information science and technology. Finally, the FNA group focuses on highly relevant device-orientated nanoscience that exploits spin-dependent and magnetic properties to realize nanodevices such as (magnetic) data storage, memory, logic and sensor applications.

The scientific output of all four groups in the NQP cluster is of a very high scientific quality. This opinion is evidenced by the large number of publications in top-tier journals that have significant visibility and impact. The four participating groups in NQP have a MJNS (MNCS) score in the range

1.5-1.6 (1.4-1.8), indicative of them being significantly above the world average in their respective fields. However, the committee found that the international visibility of some groups did not match this exceptional scientific performance on paper. The NQP cluster research has close connections with research in Delft, Amsterdam and at AMOLF. On the side of Quantum Materials NQP is exceptionally strong in the growth of nanowires and related physical characterization of their quantum transport properties, in close collaboration with QuTech (TUDelft) and Microsoft.

**Relevance for Society**

The research themes addressed by the NQP cluster have particularly strong societal relevance in the areas of (i) Energy and Sustainability, (ii) Photonics and (iii) Novel Information Technologies. For example, the AND group has a dual focus on energy science / sustainability (i) and emergent quantum information technologies (iii); the M2N group is strongly active in the area of solar cells and fuels (i) and the PSN group performs research that is highly relevant to next generation integrated photonics (ii), including optical interconnects and low energy optical switching (i). The research themes explored by FNA enable disruptive solutions for memory and logic, such as magnetic racetrack memory based on current-driven motion of information along magnetic nanowires in a 3D architecture with optical control (iii). The evaluation committee advises to further strengthen all of these aspects in view of large scale industrial and academic activities (e.g. Photon Delta, National Gravity program on *Integrated Nanophotonics*) and the excellent industrial capability in the environment of TU/e. Furthermore, consolidation of activities to allow stronger competition at a European level and flagships / missions directed towards energy science and photonics are entirely feasible, for example in the framework of the EuroTech alliance.

**Viability**

While the groups are all financially viable, with good funding streams and good opportunities for high impact research outputs, there is a need to create new staff positions in order to secure the long-term prospects for the cluster. The career stage spectrum of senior and junior scientists is well balanced, although some groups, such as the newly formed AND group are still under-critical. The evaluation committee strongly supports creating a new PI position in the area of “MetaPhotonics” that strives to address research themes at the interface of spintronics-photonics-electronics. Such a position would be an interesting crossover position between PSN and FNA and would undoubtedly serve as a linker to other clusters, other groups and even other faculties within the TU/e.

### 2.2.4 Qualitative and quantitative assessment of the research quality

**Score: 1-2**

In summary, the panel judges that the research quality of the Applied Physics department at the TU/e is very good to excellent. As evidenced by the publication highlights, which include numerous papers in high-profile journals, and important marks of recognition received by faculty members (including prestigious scholarships and prizes, such as a Spinoza award, and major research grants, including several ERC Grants and more than 10 grants in the NWO VENI/VIDI/VICI scheme), the research groups in the department are in certain research areas among the most influential groups in the world, while in other research fields there seems to be a clear potential for achieving such a position in the near future. The new structure that the department has implemented with the definition of three research disciplines (FBS, PB and NQP), the novel opportunities for starting new research directions and strengthening existing ones via the Sector plan and the establishment of six Cross-disciplinary Research Themes within the TU/e, offer the department significant opportunities for further strengthening of its research program. These opportunities are reinforced by the department´s sound policy of striving for research excellence by investing in talented young researchers, such as tenure-track researchers. Benefitting from the environment of a larger research group, these tenure-trackers are given access to state-of-the-art infrastructure and a chance to prove themselves, with the clear prospect that tenure is the desired outcome of a successfully executed research program.

At the time of the current evaluation, the process of defining the departmental research strategy is clearly still a work in progress. When defining the additional research directions for which funds may become available shortly, the department needs to strike a balance between strengthening existing research directions (which have the advantage that they can build on existing strengths, at the expense of narrowing the scope of the possible choices), as opposed to starting entirely new research directions that are not (yet) closely connected to the existing research activities. Furthermore, the panel recommends that the department uses its healthier financial situation to become an active agent promoting interdisciplinary, collaborative research within the department, by setting up an incentive system where groups can jointly apply for modest amounts of seed money in order to start collaborative research without having to rely on external support.

### 2.2.5 Qualitative and quantitative assessment of the department´s relevance to society

**Score: 1**

The industrial eco-system in the Eindhoven area provides the TU/e with an industrial context for its research that is unparalleled in the Dutch scientific landscape. This role is clearly two-fold. On the one hand, significant research is performed within the department that is of direct interest to companies in the Eindhoven area. As such, it is understandable and fully justified that the department considers valorization as one of the three key elements of its research vision. On the other hand, students that are trained within the department are very much sought after by local industries such as ASML, who have a major need for academically trained personnel, even exceeding what the department can deliver by a significant extent.

Presently, the majority of the research groups within the department are already engaged in successful valorization activities. With the increased transparency that the new research structure provides, it is to be expected that in future an even more extensive exploitation of the department´s valorization potential will be possible. While the panel considers this desirable, it recognizes that the contribution that the department makes to the Dutch economy by way of its valorization and training activities is already clearly outstanding.

### 2.2.6 Qualitative and quantitative assessment of the department´s viability

**Score: 1-2**

The extensive reorganization that the department has undergone in the last few years has solved serious financial problems that had accumulated and has significantly improved the chances for success in crucial upcoming funding programs that are essential to the department´s development in the coming years. As attested by many of its researchers, excellent facilities exist in the new building that the department moved into a few years ago. As such, the pre-conditions for sustaining and further developing a highly successful research program are clearly given, and the realization of this goal will depend to a large extent on several key choices that the department will make regarding its research strategy in the near future.

Within the self-assessment document, and during the panel´s visit it has been evident that the department has recently carefully reconsidered its organizational structure, and with the (internal) Scientific Advisory Board a new advisory body has been introduced. While it is too early to determine the impact of these initiatives, the panel considers it likely that these novel advisory structures will play a helpful role in further shaping the department and its research strategy in the period to come. In doing so, care should be taken not to overlook some of the boards that have previously existed. It came as a surprise to the panel to learn that the Department Council had not been consulted during the preparation of the self-assessment document.

## 2.3 Quality and organization PhD programs

During its site visit, the panel interviewed a number of PhD students, who are all members of the PhD council. These PhD students expressed satisfaction with the research and training opportunities that they are given within the department. Moreover, the interviews showed that several mechanisms for monitoring the progress of PhD students towards their degree are in place and functioning, such as the formulation of a supervision and education plan, and yearly follow-up assessments. As modest complaints, a lack of uniformity across the Department regarding the implementation of soft skills training and a lack of clarity regarding the requirements for contributions to the teaching program were expressed. The panel recommends setting up a webpage for PhD-students, where these and other useful pieces of information can be collected (see also 2.4). The panel was impressed by the confidence that the PhD students expressed regarding their future careers, with most of them expecting abundant job opportunities within industries in and around Eindhoven.

It concerns the panel that only 27 out of 234 possible PhD students hired in the 2008-2013 period managed to obtain their degree within the 4 year period where a PhD salary is paid. 144 of these PhD students obtained their degree in the 5th or 6th year, i.e. at a point where the payment of a PhD salary would typically have been discontinued, and 13 of them even in the 7th year. In addition, the panel considered the number of PhD students who failed to get their PhD (29) to be relatively high, although information was missing regarding the amount of time that these students had – on average – been enrolled.

As part of the documentation accompanying the self-assessment, the panel received a position paper (unknown to the students!) that was formulated by a TU/e-wide steering committee in 2016. This position paper contains many useful recommendations, both for monitoring work progress and training of the students while working towards their degree, as well as preparations for their career upon completion of the PhD, which as yet have not been implemented. The panel recommends that the department enters into a discussion with the PhD council on the contents of this position paper, and then proceeds to the implementation of those recommendations that find wide support within the faculty and the PhD student population.

## 2.4 Quality and organization of research integrity policy

The department´s policy on research integrity follows the Netherlands Code of Conduct for Research Integrity (2018) and the TU/e Code of Conduct (2014), which itself follows the Netherlands Code of Conduct for Academic Practice (2014). These policies are in place to ensure an open scientific climate and provide procedures in case of conflict or (academic) misconduct. The policy for research data management includes logging of laboratory journals, and lies in the responsibility of the principal investigator.

In view of rapid, on-going changes in the way that scientific results are being published (e.g. increasing requirements of “open access” publishing, the emergence of predatory publishers, and the rapid rise in plagiarism cases facilitated by electronic-only publishing), the panel recommends that, in future, the department takes a more active role in ensuring research integrity, by installing a set of procedures for publishing papers, and storing and publishing scientific data, that is then adhered to by all research groups. Useful steps could include, among other things, the adoption of an internal refereeing scheme, the implementation of anti-plagiarism software and, as demanded by several funding organizations outside the Netherlands, the establishment of a repository where all materials that were used for the preparation of a paper are stored beyond the control of the authors.

## 2.5 Quality and organization of diversity policies

It is to be commended that the department recognizes the importance of supporting diversity in both the student and the faculty populations. It is indeed impressive that 35% of Ph.D. students are female. Just that fact alone indicates that the Department provides a supportive and inclusive environment for young women students – a solid foundation on which to build. Moreover, the department is actively pursuing a number of routes to increase the number of female faculty.

While our recommendations focus mainly on gender (as this was the focus of the panel discussion), diversity is a much broader issue. It is important that the Department also recognizes these wider aspects and fosters a culture of diversity in terms of ethnic, religion, race, etc. to ensure a fully inclusive research environment.

**Female graduate students**

With respect to the Ph.D. students, it would be helpful to articulate and put in place specific plans for recruiting the excellent female students that exist in Eindhoven and other universities (including international universities). Currently, there does not seem to be a set of particular guidelines and actions for encouraging women to join the Ph.D. program. One possibility is for the female graduate students to organize lunches for the undergraduates where they talk about their experiences and describe their work. The graduate students can also hold a poster fair and reach out to encourage female undergraduates to attend. It is frequently the case that the excitement of doing science is best conveyed through the interaction of students of roughly the same age; this activity also helps the PhD students to further enhance communication skills and confidence.

In that context, to ensure that there is a pipeline connecting women across different ages and educational stages, it could be useful for the female undergrad and graduate students to take leading roles in presentations or bringing hands-on exhibits to local high schools. An open-day in the department for high school girls would also be effective—allowing the girls to participate in prepared hands-on demonstrations and to meet successful women from the research staff. Maintaining this pipeline is critical to ensure that future generations of young women become engaged in physics.

Another issue to consider is the retention of women in the Ph.D. program. To this end, regular gatherings among the female graduates can be an effective method for making sure that they have a venue for discussing and airing their concerns. Additionally, it is important that the students are given a list of people and resources that they can contact to address any of their concerns – a quarterly meeting of a Department Inclusion and Diversity committee involving staff and students (not just women) could provide a useful forum to drive and monitor initiatives that arise. Making the list of committee members available on a website would be highly useful and give the initiative more visibility.

With respect to their future career options, one approach is to invite some of the many successful female scientists from industry to come and discuss their work—for example, at one of the lunch-time gatherings for the students, or at a departmental seminar. Similar activities can be helpful for female students wishing to pursue careers in academia—women faculty from the University or other nearby universities can come and talk about their career paths. If a departmental seminar speaker is a female scientist, then a luncheon could be arranged where students can get to meet and talk with the speaker – it is important that both female and male students have opportunities to interact with outstanding women role models in science.

**Hiring female faculty**

There are many exceptional women in science and engineering, but a pro-active approach must be taken to attract them to apply for the faculty positions. One means to achieve this goal is to identify bright students at the Ph.D. level. For example, the faculty in the department could meet with female speakers or poster presenters at the annual meeting held in Veldhoven. Since the program is

available before the meeting, the faculty attending could each take responsibility to contact and meet with a few of these students. This strategy is used in the US at the annual meeting of American Chemical Engineering Society and has proven to be an effective tool for recruiting.

One of biggest stumbling blocks for attracting female faculty (especially senior faculty) is addressing the two body problem. If the spouse is interested in an academic career, then creating a position in the appropriate department in the University for a spouse who brings exciting qualifications and expertise would go a long way in addressing this problem. Such positions could be considered as opportunity hires, where hiring the spouse could bring new opportunities and research directions to the University.

Another potential way of addressing this problem is to build on the availability of industrial positions in Eindhoven and the local area. In particular, the department can take advantage of its contacts in industry to help provide the spouse with interesting and valuable career opportunities.

While addressing the two body issue is challenging, it is a particularly good investment. Namely, if both partners are happily employed, there is a greater chance that the University can retain them both.

With respect to the young faculty, setting up an effective mentoring program is critical not just for the women, but also for all early career tenure trackers (see sections 2.2 and 3.1).

**Reaching out to international scientists**

Finally, it is important to take an international perspective in trying to recruit the very best female faculty. This increases the pool of possible applicants and provides more opportunities to further diversify the faculty with respect to nationality, race and culture, as well as gender.

# 3. Recommendations

## 3.1 Recommendations for the strategy of the research unit

Building on the texts in Section 2 of this report, the panel has the following recommendations for the strategy of the research unit as a whole.

- in the upcoming strategic choices faced by the department (applications to Sector plan and TU/e-internal Cross-disciplinary Research Themes) the department needs to strike a balance between the strengthening of individual existing research directions, and the development of novel “out of the box” research directions.
- the department should consider using its healthier financial situation to become an active agent promoting interdisciplinary, collaborative research, by setting up an incentive system where groups can jointly apply for modest amounts of seed money in order to start collaborative research without having to rely on external support. The panel considers it acceptable if such an initiative goes at the expense of a 1 or 2 % reduction of the coverage percentage (currently at 90%).
- opportunities for increasing the interactions between the research groups in the department, for example modeled on the two joint annual conferences that are organized within the Plasma and Beams cluster, should be identified, in order to encourage the emergence of new ideas and innovative technologies.
- the attraction of highly-talented (in particular, female) tenure-track researchers should remain a top priority in the years to come.
- the department should increase the uniformity of the opportunities that junior faculty receive in terms of mentoring by senior faculty, in terms of publishing of research results without co-authorship of more senior faculty and in terms of the promotion of an independent research profile by means of a web presence.
- while recognizing the value of in-house collaborations, external (especially international) collaborations of tenure-trackers should be encouraged, since they are vital for the development of an independent scientific career beyond the initial stage.

Moreover, the panel has the following recommendations in relation to the three research disciplines within the department:

**Fluids, Bio and Soft Matter (FBS)**

- the research in the area of polymers and soft matter provides many opportunities for start-up companies (especially at the border of software and energy or software and biomedicine), which is an important area to explore.
- future faculty appointments at the boundaries between the individual research groups have the potential of further enhancing the cohesion of the cluster.
- it might be useful to explore additional opportunities for the valorization of current research activities in the areas of energy storage and medical diagnostics.

**Plasmas and Beams (PB)**

- opportunities for further increasing the interactions between the plasma groups of the Plasma and Beams Cluster beyond the two joint annual conferences should be identified, to encourage the emergence of new ideas and innovative technologies.

- the planned recruitment of additional research staff should provide an opportunity to develop constructive interactions between research groups and new research topics (e.g. within the area of plasma-material interaction).
- the panel supports the proposal to recruit into the area of elementary processes that underpin the dynamics of plasmas (cross sections, transport, etc.); however, it is important that the high impact scientific opportunities are identified, as well as sustainable funding routes.
- plasma technologies provide many opportunities for commercial spin-offs (including start-up companies), and the TU/e is well-positioned to explore these with regional industry – this is an important area to explore.

**Nano, Quantum and Photonics (NQP)**

- the planned strategy to install a new professorship in the field of "quantum transport" to accommodate / mitigate the structural developments occurring elsewhere in the Netherlands is entirely sound.
- the M2N group should further exploit the state-of-the-art nanofabrication capabilities at the TU/e to perform nanoscale studies of photo-physical processes occurring at length scales below those normally amenable to mean-field treatments. Here, an attractive and accessible opportunity for developing sustainable energy technologies could center on the exploration and deliberate control of interfacial solid-state and molecular architectures down to nanoscopic dimensions, as well as obtaining a fundamental understanding of the impact of such architectures on the optimized conversion of excitations and energies. The realm of interfacial tailoring to be investigated is thereby almost as unlimited as it is unexplored and, potentially, provides significant additional scope for exploration.
- research activities on atomically thin van der Waals 2D-materials and perovskites should be further developed. In particular, the committee welcomed the new activity of new and early career assistant / tenure-track professors within the PSN group, within the context of "nanophotonics" and "semiconductors".
- the efforts to enhance research themes having strong societal relevance in the areas of (i) Energy and Sustainability, (ii) Photonics and (iii) Novel Information Technologies should be continued and further strengthened. Here, the panel recognized the potential for large-scale joint industrial and academic activities that capitalize on the excellent industrial environment in the environment of TU/e.
- research activities should be combined and directed to allow stronger competition at a European level, for example in the framework of the EuroTech alliance. Moreover, the groups should fully engage with flagships / missions directed towards energy science and photonics.
- research in the highly topical and broad field of quantum electrodynamics with nano-mechanical systems (cavity quantum opto-mechanics) would be perfectly suited to the environment at the TU/e (PSN and Nanofab) and would create interfacial synergies between the NQP-cluster and e.g. the Fluids, Bio and Soft Matter (FBS) cluster. Here, strong activities exist in bio-sensing that could find key synergies with e.g. the MBx group and others.

### 3.2 Recommendations for the research unit's PhD programs

- a webpage should be set up for PhD-students, where information regarding the availability of soft-skills training, the requirements for contributions to the teaching program and other useful pieces of information are collected.
- the department should enter into a discussion with the PhD council on the contents of the position paper on PhD training that was formulated by a TU/e-wide steering committee in 2016, and then proceed to the implementation of those recommendations that find wide support within the faculty and the PhD student population.

### 3.3 Recommendations for the unit's research integrity

- the department should take an active role in ensuring research integrity, by installing a set of procedures for publishing papers, and storing and publishing scientific data, that is then adhered to by all research groups. Useful steps could include, among other things, the adoption of an internal refereeing scheme, the implementation of anti-plagiarism software and the establishment of a repository where all materials that were used for the preparation of a paper are stored beyond the control of the authors

### 3.4 Recommendations for the unit´s diversity development

- specific plans should be put into place to recruit excellent female students for the PhD program. Possible actions include lunches organized by the female graduate students or a poster fair. Regular gatherings among female graduate students and the availability of a list of resources (see 3.3) can help the retention of women in the PhD program.
- female undergraduate and graduate students should take leading roles in presentations or bringing hands-on exhibits to local high schools.
- a Department Inclusion and Diversity committee could be established involving staff and students to drive and monitor useful initiatives.
- successful female scientists from industry and female faculty from the University or nearby universities should be invited to come and discuss their work. If a departmental seminar speaker is a female scientist, then a luncheon for female students could be arranged to meet the speaker, noting it is important for both female and male students to experience good female role models.
- a pro-active approach must be taken towards attracting women to faculty positions, by identifying bright students at the PhD level, e.g. exploiting the annual meeting held in Veldhoven. Attending faculty could each take responsibility to contact and meet with a few of these students.
- when addressing a two body problem, the department should take advantage of its contacts in industry to help provide the spouse/partner with interesting and valuable career opportunities.
- the department should take an international perspective in trying to recruit the very best female faculty.

### 3.5 Recommendations for future evaluation procedures

The current evaluation was organized and the self-evaluation assessment was written according to the SEP Protocol 2015-2021 defined by the KNAW, VSNU and NWO. In the opinion of the panel, the materials made available in line with this protocol lacked essential information needed for an

assessment of the plausibility of the future strategy of the department. After all, past performance is one of the more reliable predictors of future performance. Accordingly, the panel recommends that in future evaluations the following materials are made available ahead of time:

- An overview of the number of researchers (including postdocs, PhD students, and MSc/BSc students) in each research group, as well as the technical support available to this group.
- The level of 1st, 2nd and 3rd Tier funding acquired by the research group over the evaluation period.
- The number of invited talks in conferences and seminars at other institutions presented by members of the research group, as well as any honors, prizes and awards received.
- An overview of existing national and international collaborations of the research group, including relevant information about their nature.
- An overview of the contributions of the members of the research group to teaching.
- An overview of the publications by each research group (including the title and a complete list of authors, with group members underlined) and the citations of these publications, as well as any patents submitted and/or awarded.
- An overview of outreach activities by members of the research group, such as popular lectures, programs for high school students, etc.

Moreover, the panel felt that it would be highly beneficial if, in future, the format of the current panel evaluation, consisting of a day-long session of discussion meetings, would be complemented by laboratory visits and informal, one-on-one interactions with staff members (including postdocs and PhD students), for example in the course of a poster session.

# 4 Appendices

### 4.1 Short CVs of the members of the assessment committee

## Anna Balasz

Anna C. Balazs is a Distinguished Professor of Chemical Engineering and holds the John A. Swanson Endowed Chair in Engineering at the University of Pittsburgh. She received her B.A. in physics from Bryn Mawr College in 1975 and her Ph.D. in materials science from the Massachusetts Institute of Technology in 1981.

Her research involves developing theoretical and computational models to capture the behavior of polymeric materials, nanocomposites and multi-component fluids. Balazs is a Fellow of the American Physical Society, the Royal Society of Chemistry, and the Materials Research Society. She was a Visiting Fellow at Corpus Christi College, Oxford University. She has served on a number of editorial boards, including: *Macromolecules*, *Langmuir*, *Accounts of Chemical Research*, *and Soft Matter.* She was Chair of the American Physical Society Division of Polymer Physics in 1999-2000. She received a *Special Creativity Award* from the National Science Foundation. In 2003, she received the *Maurice Huggins Memorial Award* of the Gordon Research Conference for outstanding contributions to Polymer Science. Recently, she received the *American Physical Society Polymer Physics Prize* (2016), the *Royal Society of Chemistry S F Boys-A Rahman Award* (2015), the *American Chemical Society Langmuir Lecture Award* (2014) and the *Mines Medal* from the South Dakota School of Mines (2013).

## Jonathan Finley

Jonathan Finley studied Pure and Applied Physics at the University of Manchester obtaining a 1st class degree in 1993. After completion of his degree he moved to the University of Sheffield where he completed his PhD in 1997 under the guidance of Prof. M. S. Skolnick (FRS), working on the exploration of ballistic electron transport in GaAs-$Al_xGa_{(1-x)}As$ based heterostructures, probed using optical methods. Subsequently, he moved to Germany, supported by a Royal Society European Fellowship (1997-1998) where he joined the group of Gerhard Abstreiter at TU-Munich, working on the spectroscopy of semiconductor quantum dots. After returning to the University of Sheffield (1999-2002), where he worked on collective phenomena in semiconductor microcavities, he returned to Germany in 2003 as a Junior Group leader at the *Max Planck Institut für Quantenoptik* in Garching. Shortly afterwards, he was appointed as C3 professor for Experimental Physics at the TU-Munich in 2003. Over the following eight years he built up a research profile working in the fields of spin-qubits in semiconductor quantum dots, nano-photonics and semiconductor-based cavity QED. In 2013, he was promoted to a personal chair (W3) for Semiconductor Nanomaterials and Quantum Systems and made a full Director of the Walter Schottky Institut (www.wsi.tum.de), researching semiconductor quantum optics, semiconductor nanomaterials and exploring their use in emergent emergent information and photonic technologies.

Jonathan Finley is recipient of several awards and honours including the University of Manchester, U.K., undergraduate prize in physics (91,92 and 93), Royal Society Individual Fellowship (1998), Goldene Kreide from Fachschaft für Physik und Mathe (TUM 2004, 2006, 2007, 2008, 2011, 2012) for Excellent Teaching, Deutsche Physikalische Gesellschaft (2007), Walter Schottky Prize for Festkörperforschung. Young Scientist Prize, International Symposium on Compound Semiconductors (2008), Preis für gute Lehre des Staatsministers für Wissenschaft, Forschung und Kunst (2010) and TUM Exzellenz in der Lehre Preis (2011). Moreover, Jonathan Finley served as the dean of studies in the Department of Physics at TUM 2009-2012.

Jonathan Finley is author of about 280 publications during his research career to date attracting about ten thousand citations, including research manuscripts, book chapters and review articles. According to Web of Science (Google Scholar) his h-index=40 (h-index=46) and a full publication list can be found via his Google Scholar page.

## Niek van Hulst

Niek van Hulst studied Astronomy and Physics, and obtained his PhD (1986) in Molecular & Laser-Physics at the University of Nijmegen (the Netherlands), on microwave-laser double resonance molecular-beam spectroscopy of molecules seen in interstellar clouds. After research periods on non-linear optics of organic materials, integrated optics, atomic force and near-field optical microscopy, in 1997 he became full Professor in Applied Optics at the MESA+ Institute for NanoTechnology, University of Twente (the Netherlands) with focus on nanophotonics, optical scanning probe technology and single molecule detection.

In 2005, attracted by the Catalan quality-based science policy, he started as ICREA Research Professor and senior group leader at ICFO - the Institute of Photonic Sciences, within The Barcelona Institute of Science & Technology. Also at ICFO, he heads the Academic Program and the NanoFabrication Laboratory. Niek van Hulst coordinates the Spanish CONSOLIDER network NanoLight.es.

He is recipient of the 1997 Shell stimulation award, the 2003 European Science Award of the Körber Foundation, the 2010 City of Barcelona Prize, the 2017 EPS Prize for Fundamental Aspects of Quantum Electronics and Optics; OSA-fellow. He received ERC Advanced Investigator Grants in 2010 and 2015; and an ERC Proof of Concept in 2016.

Niek van Hulst is author of 233 refereed papers and 33 proceedings (WOS), attracting ~13300 Citations. His papers receive on average 58 Citations/paper. According to Web of Science his h-index is 62.

## Eckart Meiburg

Eckart Meiburg studied Mechanical Engineering at the Technical University Karlsruhe from 1976-1981. After spending one year in the Chemical Engineering Department at Stanford University as a DAAD fellow, he returned to Germany to complete his PhD research at the DLR in Göttingen and at the Technical University of Karlsruhe, on the topic of computational vortex dynamics. After postdoctoral studies on viscous fingering instabilities in multiphase porous media displacements at Stanford, he was appointed Assistant Professor of Applied Mathematics at Brown University in 1987. In 1990, he moved to the Aerospace Engineering Department at the University of Southern California, where his research focused on multiphase and porous media flows, as well as environmental flow phenomena such as gravity and turbidity currents. In 2000, he moved to the Mechanical Engineering Department at the University of California Santa Barbara, where he is currently Distinguished Professor of Fluid Dynamics.

Eckart Meiburg is a fellow of the American Physical Society and the American Society of Chemical Engineers. He has received a Senior Research Award of the Alexander von Humboldt Foundation, and a Senior Gledden Fellowship of the Institute of Advanced Studies at the University of Western Australia. He was the Lorenz G. Straub Award Keynote Speaker at the University of Minnesota, the Ronald F. Probstein Lecturer in Engineering Science at MIT, and the Shimizu Visiting Professor at Stanford University. In 2017-18 he served as Chair of the Division of Fluid Dynamics of the American Physical Society. He is Associate Editor of Physical Review Fluids.

## Antoine Rousseau

Antoine Rousseau is Directeur de Recherche (CNRS Professorship). He defended his PhD in 1994 at Paris-Sud University (Orsay), followed by Habilitation in 2002. His early research fields have been microwave plasma physics and chemistry up to 2000 ; Since 1998, he has been working on air purification by plasma – catalyst coupling, and more recently to biomedical applications of plasmas such as dermatology, cancerology or agronomy.

His scientific expertise is related to streamers physics, dielectric barrier discharges, plasma surface interaction, plasma catalyst coupling, plasma with liquids (physics and chemistry), plasma diagnostics such as absorption spectroscopy, emission spectroscopy.

Antoine Rousseau has been director of the Laboratoire de Physique des Plasmas (LPP) at Ecole Polytechnique, Palaiseau from 2008 to 2012, deputy for plasma physics at CNRS (2003-2008 and 2012-2016) and coordinator of several projects, such as French network GdR CATAPLASME (2002-2009), CNRS program PLASMAMED and German-French Exchange program PROCOPE (1999-2001 and 2006-2008).

## Marc Vrakking (chair)

Marc Vrakking studied Applied Physics at the Eindhoven University of Technology from 1981-1987. After completion of his degree on the basis of research performed in the group of Prof. Herman C.W. Beijerinck, he performed his PhD at UC Berkeley, working in the group of Chemistry Nobel Laureate Prof. Yuan-Tseh Lee. The main theme of his PhD work, completed in 1992, was a study of the hydrogen exchange reaction using high-resolution laser spectroscopy techniques. After a short postdoctoral appointment, he became a postdoctoral fellow at the National Research Council in Ottawa, working in the ultrafast laser physics group of Profs. Paul Corkum and Albert Stolow.

Upon returning to the Netherlands in 1995 on the basis of a KNAW fellowship, he took a position at the Vrije Universiteit Amsterdam, and shortly thereafter, became a groupleader at the FOM Institute for Atomic and Molecular Physics (AMOLF) in Amsterdam. At AMOLF, he developed a research program focusing on the development and application of ultrashort extreme ultra-violet (XUV) laser pulses based on using high-harmonic generation, and led one of the first teams to demonstrate the generation of attosecond pulses. In 2010, he became a director at the Max-Born Institute (MBI) in Berlin in combination with a full professorship at the Freie Universität Berlin. At MBI, he currently heads the Attosecond Science Division.

Marc Vrakking was recently appointed as Editor-in-Chief of the Journal of Physics B. He is a member of the management board of Laserlab Europe, a permanent member of the CEA visiting committee, the chairman of the Scientific Advisory Board of the Amsterdam Research Center for Nano-Lithography (ARCNL), and has served on multiple ERC panels.

## Howard Wilson

Howard Wilson studied physics at the University of Durham during 1982-1985, followed by a PhD in theoretical particle physics at University of Cambridge during 1985-1988. He then moved to UK Atomic Energy Authority to work on the national fusion energy programme, employed as a theoretical plasma physicist.

In 2005 he moved to University of York Physics Department as Professor of Plasma Physics to lead the development of a new fusion energy group there. He established the York Plasma Institute in 2012, which has now grown to 17 faculty staff and about 70 post-docs, Masters and PhD students working in Laser-Plasma Interactions, Low Temperature Plasmas and Magnetic Confinement Fusion. In 2017 he was appointed as UK Atomic Energy Authority Research Program Director, with responsibility for the UK national fusion research program – a position he holds alongside his Chair at York.

He is Director for a multi-institutional national doctoral training program in fusion energy, which currently has over 60 PhD students enrolled across five of the UK's top universities.

Howard's personal research interests center around the theory of plasma instabilities, eruptions and turbulence, with a particular interest in tokamak plasmas. He also works on the design of compact fusion reactors. He is a member of the IAEA Nuclear Fusion journal Editorial Board and a representative on the Plasma Physics Commission C16 of IUPAP.

## 4.2 Site visit program

| **December 11, 2018** | **Pullman Hotel** |
|---|---|
| During the day | Arrival committee members |
| 18:00–20:00 | Dinner with Faculty Board<br>Topic: Getting acquainted, specifying questions<br>Baaijens, Kroesen, Cottaar, Van Wevelingen, Swagten, Van Himste. |
| 20:00–22:00 | Committee Private kick-off meeting |

| **December 12, 2018** | **TU/e Applied Physics** |
|---|---|
| 09:00–09:30 | Faculty Board<br>Topic: department strategy and management<br>Kroesen, Cottaar, Van Wevelingen, Swagten, Van Himste. |
| 09:45–10:15 | Scientific advisory council<br>Topic: The future department strategy (forward looking)<br>Clercx, Fiore, Kessels. |
| 10:30–11:00 | department council<br>Topic: Staff representatives' view on department.<br>department council, members. |
| 11:15–11:45 | Representatives Tenure trackers<br>Topic: View on management, research and support.<br>Mackus, Duran Matute, Gelderblom, González Curto, Janssen (Liesbeth), Proll, Tao. |
| 12:00–12:30 | Representatives PhD council<br>Topic: View on management, research and support.<br>PhD council, members. |
| | |
| 12:30–13:15 | Committee Lunch |
| | |
| 13:30–14:00 | Representatives 'Nano/Quantum' research cluster<br>Topic: Research (strategy, management) of this cluster.<br>Bakkers, Janssen (René), Fiore, Koopmans. |
| 14:15–14:45 | Representatives 'Flow/Bio' research cluster<br>Topic: Research (strategy, management) of this cluster.<br>Clercx, Huinink, Prins, Storm. |
| 15:00–15:30 | Representatives 'Plasmas/Beams' research cluster<br>Topic: Research (strategy, management) of this cluster.<br>Kessels, Kroesen, Lopes Cardozo, Luiten. |
| 16:00–16:30 | Committee wrap-up<br>Topic: First impressions, committee only. |
| | |
| 16:45–17:15 | Faculty Board<br>Topic: Delving deeper, remaining questions.<br>Kroesen, Cottaar, Van Wevelingen, Swagten, Van Himste. |
| 18:00-20:00 | Dinner, committee only |

| **December 13, 2018** | **Pullman Hotel** |
|---|---|
| 9:00-12:00 | Meeting with Faculty Board + Representatives research clusters<br>Kroesen, Cottaar, Fiore, Clercx, second half of the morning Kroesen only |
| 12:00-16:00 | Private final meeting, drafting report |

| | |
|---|---|
| 16:00–16:30 | Report first results to department Board<br>Kroesen, Cottaar, Van Wevelingen, Swagten, Van Himste. |

| **December 14, 2018** | |
|---|---|
| During the day | Departure committee members |

### 4.3 Quantitative data on the research unit's composition and financing

The following information on the department´s composition was provided as a handout during the on-site visit.

| GROUP | | SCIENTIFIC STAFF (FTE) | | | | | PhD Graduations | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Name | Full prof. | Assoc. Prof | Assist. Prof | Postdocs | | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | SUM |
| AND | Advanced Nanomaterials and Devices | 1 | 1 | | 1 | | | 3 | 3 | 1 | 6 | 1 | 14 |
| CQT | Coherence and Quantum Technology | 1 | 2 | 2 | 2 | | 1 | 4 | 1 | 4 | 3 | 1 | 14 |
| EPG | Elementary Processes in Gas discharges | 1.6 | 1 | 5 | 3 | | 10 | 6 | 1 | 6 | 7 | 4 | 34 |
| FNA | Physics of Nanostructures | 2.2 | | 1 | 1 | | 2 | 2 | 3 | 3 | 5 | | 15 |
| FUSION | Science and Technology of Nuclear Fusion | 1.2 | 1 | 1 | 1 | | 3 | 6 | 4 | 5 | 3 | | 21 |
| MBx | Molecular Biosensors for Medical Diagnostics | 0.5 | 1 | 2 | 3 | | 1 | 5 | | | 1 | | 7 |
| M2N | Molecular Materials and Nanosystems | 2.2 | 2 | | | | 3 | 3 | 2 | 1 | 2 | 2 | 13 |
| PMP | Plasma and Materials Processing | 1.4 | 3 | 2 | 8 | | 6 | 13 | 5 | 2 | 4 | 2 | 32 |
| PSN | Photonics and Semiconductor Nanophysics | 2.7 | 1 | 2 | 6 | | 4 | 4 | 7 | 5 | 11 | 1 | 32 |
| TPM | Transport in Permeable Media | 0.4 | 2 | | 1 | | 3 | 5 | 2 | | 3 | 1 | 14 |
| TPS | Theory of Polymers and Soft matter | 2 | | 3 | 1 | | 2 | 2 | 5 | | 4 | | 13 |
| WDY | Turbulence and Vortex Dynamics | 4 | | 3 | 5 | | 5 | 10 | 8 | 5 | 3 | 3 | 33 |
| CCER | Center for Computational Energy Research | 0.8 | 0.4 | 1 | | | 2 | 1 | | 2 | | | 5 |
| (None) | | | | | | | 1 | | | | | | 1 |
| SUM | | 21 | 14.4 | 22 | 32 | | 44 | 64 | 41 | 34 | 53 | 15 | 250 |

Within the self-assessment document the following financial information were provided:

| Applied Physics | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Forecast 2018 |
|---|---|---|---|---|---|---|---|---|
| Structural income | 9.4 | 8.3 | 8.6 | 8.8 | 8.6 | 9.0 | 9.3 | 9.8 |
| Structural cost | 11.8 | 11.4 | 12.0 | 11.6 | 11.6 | 12.3 | 12.9 | 12.6 |
| Difference | 2.4 | 3.2 | 3.4 | 2.8 | 3.0 | 3.3 | 3.6 | 2.8 |
| Coverage ratio | 79% | 72% | 72% | 76% | 74% | 73% | 72% | 77% |

*Figure 2: Development of the Department's financial household*

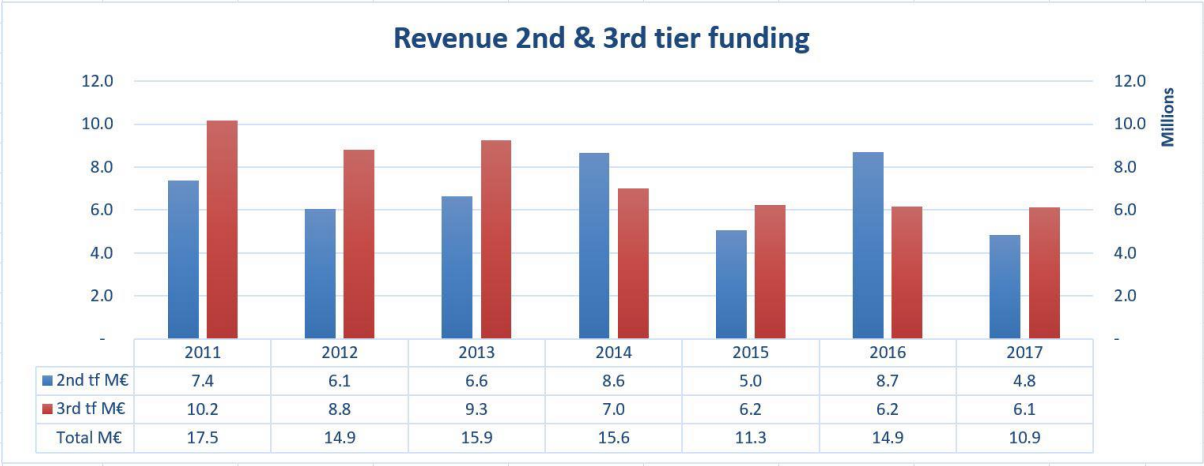


*Figure 3: Development of 2nd and 3rd tier financing, excluding FOM, M2i, Zwaartekracht and funding from AccTec (2014; M€ 0,2, 2015; M€2,4, 2016; M€5,1, 2017; M€4,0).*

## 4.4 Explanation of the categories utilized

Table 1, meaning of categories in SEP 2015 - 2021

| Category | 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. |