



Evaluation 2017 - 2022

NWO institute AMOLF
Physics of functional complex matter

© 2024 Academion

www.academion.nl
info@academion.nl

Project code P2228



Contents

1. Foreword by the committee chair	4
2. Procedure	5
2.1 Scope of the evaluation	5
2.2 Composition of the committee	5
2.3 Independence	6
2.4 Data provided to the committee	6
2.5 Procedures followed by the committee	6
3. Evaluation of AMOLF 2017-2022	8
3.1 About AMOLF	8
3.2 Mission, vision and strategy	8
3.3 Research Quality	10
3.4 Societal Relevance	12
3.5 Viability	13
4. Executive summary	18
4.1 Conclusion	18
4.2 List of recommendations	18
Appendix 1: SEP Questions Evaluation NWO institutes	19
Appendix 2: Programme of the site visit	21
Appendix 3: Quantitative data	22

1. Foreword by the committee chair

'AMOLF provides excellent value for money'. With those words I concluded the wrap up of the site visit we conducted at AMOLF on 11-12 December 2023. In this, 'we' are the members of the international review committee, as listed on page 5 of this report, who were tasked by NWO to conduct a research evaluation over the period 2017-2022, according to the SEP protocol 2021-2027. This report is the final outcome of this evaluation.

The committee was overall very impressed by the excellent research at AMOLF, conducted in a framework of exciting, forward-looking research themes, and highly developed disciplinary centers of expertise. The research successes arise from a productive and collegial interplay between the members of the scientific staff and the various support division, as well as with many external partners. AMOLF is regarded nationally as exemplary on its diversity and inclusion efforts.

With all the positive remarks, the committee of course also found points for possible improvement, condensed into a lists of concrete recommendations. These concern varying aspects, relating for example to the shaping of PhD policies in the complex setting of the interplay with differing universities.

Being part of the evaluation committee was felt by all committee members as very inspiring. The self-evaluation report was excellently written and gave a very good preparation for the site visit. The visit itself was equally well organized, and gave the possibility for open and insightful dialogues and stimulating visits to the labs and support divisions. Throughout we encountered enthusiastic 'AMOLF-ers', who were proud of their work and their institute and also expressed themselves clearly and openly on possible points of improvement, very much in the spirit of the internal discussions that underly the successes of AMOLF.

We thank everyone who has helped in one way or the other with the research evaluation. Of course all those at AMOLF, who contributed to the self-evaluation report and the site visit, under the engaged leadership of AMOLF's director Prof. Dr. Huib Bakker and Institute Manager Dr. Paula van Tijn. The committee felt very fortunate to have Elia Bogers MSc as secretary. She did a truly outstanding job in the guidance of our work and the lead-up to this report. We are furthermore very grateful for the fine help of Dr. Thecla van Wageningen of NWO-I.

We wish the AMOLF community the very best in the forthcoming years and look forward to further exciting and valuable outcomes. Hopefully this report will present a useful contribution in the path towards these.

Prof. dr. ir. Hans Hilgenkamp
Chair of the Evaluation Committee.

2. Procedure

2.1 Scope of the evaluation

This evaluation was carried out as part of the six-yearly evaluation of the nine research institutes of the Dutch Research Council (NWO). NWO asked evaluation committees of external peers to perform an evaluation of its research institutes over the period 2017-2022. Evaluation bureau Academion acted as independent intermediary to safeguard the quality of assessment, providing secretaries for each of the site visit and helping the institutes and evaluation committees prepare and execute the site visits together with NWO-I, the institute organization of NWO.

The evaluations were carried out according to the Strategy Evaluation Protocol 2021-2027 (SEP), the protocol for research evaluations in the Netherlands, agreed upon by NWO, the Royal Netherlands Academy of Arts and Sciences (KNAW) and the Universities of the Netherlands (UvNL). The committees were requested to carry out the evaluations according to a list of questions derived from the main assessment criteria of SEP (see appendix 1). The assessment was to include a backward-looking and a forward-looking component. The committees were asked to judge the performance of the institute based on the list of SEP questions and to offer its written conclusions as well as recommendations based on considerations and arguments. The main assessment criteria are:

- Research Quality;
- Societal Relevance;
- Viability.

During the evaluation of these criteria, the committees were asked to incorporate four specific aspects relating to how the institute organizes and actually performs its research, its composition in terms of leadership and personnel, and how the institute is run on a daily basis. These aspects are:

- Open Science;
- PhD Policy and Training;
- Academic Culture;
- Human Resources Policy.

For more information on the SEP questions, see Appendix 1.

2.2 Composition of the committee

The committee for the evaluation of AMOLF was appointed by the Board of NWO, and consisted of the following members:

- Prof. dr. ir. (Hans) Hilgkamp (chair), Professor of Applied Physics and Nanotechnology, University of Twente;
- Prof. dr. (Teri) Odom, Professor of Chemistry, Northwestern University;
- Prof. dr. (Christy) Landes, Professor of Chemistry, University of Illinois, Urbana-Champaign;
- Prof. dr. (Andrea) Liu, Professor of Physics, University of Pennsylvania;
- Prof. dr. Rolf van Benthem, Professor of Coating Technology at TU Eindhoven and Chief Scientist Material Science at Shell;

- Prof. dr. Stephan Grill, Professor of Biophysics, Max Planck Institute of Molecular Cell Biology and Genetics.

Prof. dr. Stephan Grill was unable to physically attend the site visit, but provided the other committee members with his preliminary assessment prior to the site visit and participated in part of the site visit online.

The committee was supported by Elian Bogers MSc (Odion Onderzoek), who acted as secretary on behalf of Academion. Dr. Thecla van Wageningen was present during the site visit to support the committee on behalf of NWO-I.

2.3 Independence

Before the site visit all members of the committee signed the NWO Code of Conduct, by means of which they declared that their assessment would be free of bias and without regard to personal interest, and that they had no personal, professional or managerial involvement with the institute or its research programmes. It was concluded that the committee had no conflicts of interest. The NWO-I coordinator present during the site visit did not take part in the evaluation, but provided the committee with background information and context on the position of the NWO institute upon request.

2.4 Data provided to the committee

The committee received the self-evaluation report from the institute, including all the information required by the SEP.

The committee also received the following documents:

- AMOLF Strategic plan 2023-2028
- Tenure Track Policy
- PhD Policy
- Data management Policy
- Diversity and Inclusion Plan
- Sustainability Roadmap
- Proposal National Growth Fund Solar (in Dutch only)
- Previous SEP-evaluation 2011-2016

2.5 Procedures followed by the committee

The committee proceeded according to the SEP 2021-2027. The secretary instructed the committee chair on his role in the evaluation. In its first meeting on 13 November, the committee was briefed by the secretary on research evaluations according to the SEP 2021-2027, and by the NWO-I coordinator on the Dutch research landscape and position of the NWO institute therein.

Prior to the site visit, all committee members independently formulated a preliminary evaluation based on the written information that was provided before the site visit. During its preparatory meeting on 10 December, the committee discussed the preliminary evaluations and identified questions to be raised during the site visit. It agreed upon procedural matters and aspects of the evaluation. The site visit took place on 11 and 12 December 2023 (see the schedule in Appendix 2). After the interviews the committee discussed its

findings and comments in order to allow the chair to present the preliminary findings and to provide the secretary with argumentation to draft a first version of the evaluation report. The final evaluation is based on both the documentation provided by AMOLF and the information gathered during the interviews with representatives of the institute during the site visit.

The draft report by the committee was presented to AMOLF for factual corrections and comments. In close consultation with the chair and other committee members, the comments received were reviewed to draft the final report. The final report was approved by the Board of NWO on 22 March.

3. Evaluation of AMOLF 2017-2022

3.1 About AMOLF

AMOLF is one of the nine scientific research institutes of the Netherlands Organization for Scientific Research (NWO), conducting research on the fundamental physics and design principles of natural and man-made functional complex matter. AMOLF's research program comprises three highly interdisciplinary themes: 1) Sustainable Energy Materials, 2) Information in Matter, and 3) Autonomous Matter.

In 2023, AMOLF employs about 135 researchers (19 group leaders, 65 PhD students, 25 postdocs, and 25 undergraduate students), as well as 88 employees (79 fte) for technical and administrative support. The institute houses 19 research groups, each headed by a single group leader, with a size of 5-10 scientists per group. The research groups are organized within three departments that carry out the three research themes. The three research departments each consists of six or seven research groups. The technical and general support divisions of the institute, which also support the Advanced Research Center for NanoLithography (ARCNL), are organized in groups that are directed by the institute manager. AMOLF houses four technical engineering groups: Software Engineering, Electronics Engineering, Design Engineering, and Precision Manufacturing, and a cleanroom facility (Amsterdam NanoLab). Disciplinary knowledge is organized in five expertise centers (Nanophotonics, Chemistry & Spectroscopy, Living Systems, Modern Mechanics, and Light Management in Photovoltaics).

The AMOLF Management Team consists of the director, the institute manager, and the three department heads. AMOLF relies on base funding (direct funding) from NWO. This covers around 60% of the annual budget. The remaining 40% of the budget comes from external sources and consists of national and international competitive funding, including individual grant schemes (i.e., NWO Talent Scheme, the ERC Starting, Consolidator and Advanced Grants) and large collaborative programs with multiple partners (i.e., NWO funding schemes for collaboration with industrial partners and the European EIC Pathfinder scheme).

3.2 Mission, vision and strategy

AMOLF's mission is to understand the fundamental physics and design principles of natural and human-made functional complex matter, and to initiate and develop new research in this field in the Netherlands, in partnership with academia and industry. Examples of functional complex matter systems studied at AMOLF include metamaterials to control light, sound and motion, nanostructured solar cells, shape-morphing mechanical metamaterials, and life-like and living adaptive systems. AMOLF uses the obtained knowledge to create novel functional materials and to find new solutions to societal challenges in renewable energy, the production and use of sustainable materials, health care, and sustainable information technologies.

At the start of the strategic period 2017-2022, the institute's research program comprised four research directions: Nanophotonics, Nanophotovoltaics, Designer Matter, and Physics of Living Matter. During the strategic period, these four intertwined research lines produced multiple research projects that crossed disciplinary boundaries and showed similarity in their research questions and theoretical descriptions. These internal developments coincided with impactful national developments, including the publication of the 'National Agenda on Materials' in which AMOLF played a key role. As a result, in 2021, AMOLF rearranged its research organization into three new, highly interdisciplinary research themes:

- 1) Sustainable Energy Materials: evolution of the Nanophotovoltaics research, adding in light-driven chemistry and spectroscopy as well as topics from Designer Matter. The seven research groups share an interest in the discovery and understanding of light-driven processes and in the use of fundamental insights in (nano)photonics and (nano)materials to efficiently convert sunlight to electricity, chemicals, materials, and heat.
- 2) Information in Matter: comprises seven research groups with a strong joint interest in information processing. These groups have their roots in quite different physical systems. The common thread in these systems is that they sense, gather, and process information, and that they (can) operate at fundamental limits of performance.
- 3) Autonomous Matter: combines six research groups driven by understanding how systems autonomously organize and sustain themselves, which indicates untapped future synergies. The autonomy of these diverse systems is characterized by stochasticity, feed-backs, spatial organization, energy consumption, and optimization strategies.

The three research themes are built on five disciplines, organized in expertise centers: Nanophotonics, Chemistry & Spectroscopy, Living Systems, Modern Mechanics, and Light Management in Photovoltaics. The mission of these centers is to continuously develop new theoretical and experimental capabilities and to provide a stimulating environment for the education and training of young researchers. The expertise centers aim to position AMOLF well in discipline-oriented (inter)national collaborations and networks. The committee clearly recognizes the significance of the expertise centers in attaining AMOLF's strategic goals. However, it has been a challenge to grasp the governance structure, integration within the institute, and organization of leadership. The institute's matrix structure calls for clear organizational charts, visibility, and seamless integration of the expertise centers within the institute. The committee recommends the development of clear schematic overviews illustrating how the centers are embedded into the institute and how leadership is structured.

AMOLF aims to fulfill its national role through initiating and incubating research directions that are new to the Netherlands, and that usually develop into larger national research programs. Hiring world-class tenure-track group leaders is crucial in setting up new research themes, since they bring in expertise that shapes and strengthens the new research directions. AMOLF's ability to start new research themes is further facilitated by a dynamic turnover of its scientific staff. The outflow of senior group leaders is an important aspect for its national role in creating space to hire new group leaders. AMOLF is highly committed to recruit and train high-level scientific talent. It strives to be an attractive and internationally competitive institute. On top of that, the institute aims to play a pivotal role in (inter)national academic research by fostering a strong international position; initiating and coordinating national research programs; innovating techniques and devices in collaboration with industry and society; and providing a national facility for nanofabrication and characterization.

The committee discussed AMOLF's mission and the reorganization of its research structure into three new research themes. These themes were shaped by considering both emerging scientific trends and a robust bottom-up approach, fueled by active participation and involvement of scientific staff. Careful attention was devoted to identifying areas where AMOLF could maximize its impact. In the conversations with staff, it became clear that the institute's mission and strategic aims are well-known and broadly supported by staff. The active engagement of staff in the decision-making processes regarding the institute's future mission and research directions has not only fostered awareness but also strengthened commitment. The committee applauds the excellent bottom-up process of shaping research themes and fully supports the outcomes. The research themes are strategically chosen, capitalize AMOLF's strengths, are forward-looking, and scientifically exciting. The themes connect research groups in a novel way, centered around AMOLF's core

physical approach. The mechanistic and quantitative perspective and approach of AMOLF's research focus creates a distinctive niche in the (inter)national field of natural and human-made functional complex matter.

The outflow of senior group leaders is important to fulfil the institute's national role. It opens up opportunities to recruit new (tenure-track) group leaders bringing in novel research topics and directions. During the strategic period, two group leaders have departed from AMOLF and one group leader retired. The committee has observed historical evidence that supports this model, and is confident that it continues to be successful in the future. Various incentives exist for group leaders to explore other opportunities, including managing larger operations or research groups, and pursuing new research directions which do not fit AMOLF's research portfolio. However, the committee advises AMOLF to acknowledge scenarios where multiple group leaders leave in short periods of time or a lack of willingness among group leaders to depart, as this could potentially pose a risk to AMOLF's mission.

3.3 Research Quality

Research metrics and indicators were provided to the committee in AMOLF's self-evaluation report and additional information was presented during the site visit. The committee considered the research quality of the institute in terms of research output (i.e. refereed publications, PhD theses, and other types of publications), grants, collaborations, academic and societal recognition, and societal impact (see also chapter 3.4).

In the evaluation period (2017-2022) AMOLF published 574 papers in internationally peer-reviewed journals, delivered 66 PhD theses and 72 other types of publications. The vast majority (89%) of the refereed papers were published open access. AMOLF's publications also show its strong collaborative nature as 50% of AMOLF's papers include at least one Dutch partner institution and 50% of papers include at least one international collaborator, and only 20% is published without collaborating partners. Its main international collaborators are located in Germany (Fraunhofer institutes, FZ Jülich, Max Planck Institutes), the US (Caltech, Harvard, CUNY), France (ESPCI), the UK (Cambridge, Imperial College), Switzerland (ETH, EPFL) and Australia (UNSW). This clearly demonstrates AMOLF's capabilities of establishing topical research networks with key institutes.

AMOLF established an exemplary reputation for its existing (and past) research directions. The topics identified within the *Information in Matter* theme are forward looking and exciting, combining expertise in different fields in a unique way. This theme shows its excellence in both its outstanding theory and its new and unique experiments. Each of the research groups that comprise the theme is individually outstanding. Most important, to the knowledge of the committee there is nowhere else in the world where researchers from nanophotonics, mechanical metamaterials and living systems are talking in such a deep way about the fundamental ideas that connect their very different systems, and the panel expects that this will lead to very interesting fundamental discoveries. There is also a strong possibility of eventual applications building upon these discoveries, which will benefit society. Fundamental limits in sensing and computing inside living systems have been identified at AMOLF. In its Strategic Plan individual research groups are listed as possible international partners. The committee encourages the department to also consider IRG1 on Trainable Soft Materials at the U Chicago MRSEC, and IRG1 on Learning Metamaterials at the UPenn MRSEC, as well as the Center for Soft and Living Matter at UPenn.

The *Sustainable Energy Materials* research theme fits AMOLF's strengths as it provides excellent opportunities for fundamental and society-driven research, attracting large grants, and to establish consortia with both societal and industry partners. It comprises an excellent team of researchers. The

outstanding optics expertise has led to applications in photovoltaics and major collaborations with both energy and photovoltaics companies such as Shell and HyET Solar. With the rise of new types of chemical reactors driven by light, the research groups are also leveraging expertise in photonics to collaborate with chemical companies such as ExxonMobil, BASF, and Toyota. The urgency and scale of the energy transition requires national and international coordination of research at both industry, fundamental and applied levels. The *Sustainable Energy Materials* research theme showed to be clearly capable of such coordination, with particularly powerful coordinating efforts in photovoltaics, essential in the renewable electricity revolution.

Finally, the committee also found the fundamental nature and forward-looking topics captured in the *Autonomous Matter* research theme to be impressive. The research groups presented compelling evidence of their attractiveness as collaborative partners in research projects and consortia. Key strengths of the *Autonomous Matter* theme are the breadth and the quality at which it pursues research, from single molecules to cell biology to organoids to soft robotics, as well as the strength of its individual researchers. The breadth allows the theme to identify principles across scales, and test them in different systems. The focus on molecular assembly, artificial life, and organ-scale autonomy is innovative, and enables the theme to be at the forefront of interdisciplinary research to unravel the principles of organization of living matter.

The institute profits from outstanding scientific group leaders who are individually well-known with excellent academic reputations. Group leaders play a significant role in attracting junior talent, as was clear from various examples in the site visit. Both PhD students and postdocs expressed that their initial contacts and interviews with group leaders, along with their academic reputations, were primary motivators for starting their PhD and postdoc trajectories at AMOLF. Tenured group leaders are strongly connected to universities. Most of AMOLF's tenured group leaders hold professorships by special appointment, at total at seven different universities in the Netherlands. The committee advises to closely monitor evolving rules and regulations regarding 0% appointments at some Dutch universities, as these changes could pose a potential threat to existing university affiliations. The committee also suggests exploring shared or special appointments with Dutch academic hospitals. This could strengthen collaborations and broaden the range of opportunities for PhD students to find a suitable institute for their PhD trajectory.

An important national role of AMOLF involves stimulating the Dutch scientific landscape by engaging other academic partners in new research directions, and by initiating and nurturing national consortia in important research directions. AMOLF is a driver in the formation of national networks and collaborations by organizing symposia and workshops around its research themes. This is supported by the significant (>20) number of events including Dutch academic communities and industry.

The committee concludes that both nationally and internationally, AMOLF is recognized for its excellent academic reputation. AMOLF's scientific output is highly respected, both in terms of volume as well as in terms of quality. AMOLF's output is considered highly impactful, especially given the available resources. Research quality across all three research themes is consistently outstanding and recognized as world-class. AMOLF has been highly successful in attracting national and international competitive funding in individual grant schemes (e.g., NWO Talent Scheme and ERC Grants) and in large collaborative programs including multiple partners (e.g., NWO funding schemes for collaboration with industrial partners and European EIC Pathfinder scheme).

The facilities and administration departments provide a wide range of services for AMOLF employees and develop and maintain internal systems to facilitate the performed research. The technical support department closely collaborates with research groups to develop scientific instrumentation and new

experimental set-ups. During the site visit, the committee observed that the institute houses excellent facilities in terms of labs and equipment, but especially in terms of highly trained and valuable technical staff. AMOLF's in-house technicians develop and support the design and manufacturing of measurement equipment, electronics, and software engineering. AMOLF's four technical engineering groups boost the efficiency and quality of research and clearly play a significant role in setting up new, innovative research directions. The committee is impressed with AMOLF's cleanroom facility NanoLab Amsterdam, for fabrication and characterization of materials and devices down to the nanometre scale. It is part of the national NanoLabNL collaborative platform. This state-of-the-art infrastructure and its technical staff provide excellent service and support both the scientific community and industrial R&D users.

Both technical and administrative support staff at AMOLF are highly valued by both the management team and scientific staff. The administrative support, including ICT, Information Security, Facilities Services, Health & Safety, Finance, Communications, Secretarial office and Human Resources, is recognized as essential to foster a productive research environment. In the evaluation period, various processes were digitized and administrative software systems were updated or replaced. This includes the renewal of the financial administration software and the implementation of a new online repository for publications. Administrative support staff also plays a key role in safeguarding knowledge security, particularly in preventing the unauthorized transfer of (sensitive) information and technology. The committee also learned about the high-quality support provided in publications and grant preparations. Support staff is in high demand and regarded as true partners.

3.4 Societal Relevance

Societal relevance AMOLF's research

AMOLF covers the entire spectrum, from curiosity-driven fundamental research all the way to industrial and societal impact. Insights gained at AMOLF, on fundamental physics and design principles of functional materials, benefit society. AMOLF aims to generate impact through 5 routes, including 1) collaborative projects with industry and societal partners, 2) high-level training of scientists, 3) inventions, tech transfer and spin-offs, 4) national and international coordination efforts, and 5) outreach.

AMOLF shows strong commitment to fulfil their national role. Since 2017, AMOLF has established 35 new collaborative projects with companies, technology transfer institutes, and societal partners. Approximately 35% of its grants include industrial or societal partners. The committee is impressed by AMOLF's highly active and extensive network of societal and industry partners - hospital, energy and photovoltaics companies, chemical industry, etc. – across diverse fields of expertise, including optics, photonics, and biophysics. The committee learned about strong collaborative projects, with industry partners also starting the initial contact, underscoring AMOLF's reputation and visibility. These external collaborations not only align with the institute's longer-term vision but also opens up broader career opportunities for PhD students and postdocs. In the conversations, the committee learned that societal partners and industry acknowledge AMOLF as a strong partner, praised for listening, its ability to build sustainable relationships, and connect fundamental research to realistic societal challenges and outcomes. However, the panel received indications that AMOLF might not be as broadly known as it should be. Active efforts in (international) recruitment and outreach were not apparent in the conversations with PhD students and postdocs. The majority of junior staff members had not come across AMOLF before starting their PhD or postdoc trajectories.

AMOLF has demonstrated remarkable success in organizing and coordinating complex consortia that extend beyond individual institutions and partners. Throughout the evaluation period, their leadership is highlighted through excellently taking up leadership roles in the development and coordination of large

national consortia. Notable examples include their involvement in the national innovation agenda MaterialsNL and the National Growth Fund initiative proposal SolarNL on sustainable photovoltaics technologies. Furthermore, AMOLF has made significant contributions to the leadership of other programs including the national NWA project NL-ECO on novel energy-efficient computing and two ‘Zwaartekracht’ (Gravitation) consortium proposals with information processing at their core. AMOLF has played a central role in leading and actively engaging in three more National Growth Fund proposals: SustainableMaterialsNL, The Revolution of Smart Molecular Systems, and QuantumDeltaNL – all of which have been granted. During the site visit, compelling examples were presented, illustrating the positive outcomes when government, universities, and AMOLF get on the same page. The committee commends AMOLF on its achievements and encourages the institute to continue to invest in strong collaborations with Dutch universities while nurturing a stronger sense of community feeling.

Open Science

AMOLF has a clear and progressive data management and open access policy. In line with NWO’s PlanS (2021), AMOLF strives to publish all papers either Gold/diamond open access, Hybrid open access, or Green open access. Approximately 90 percent of its research output is accessible through these three routes. Open access and data management are strongly supported by the leadership team and form a key part of the institute’s Strategic plan 2023-2028. Researchers at AMOLF are well-informed about suitable publication avenues, with a preference for non-profit journals. However, the committee noted the cost of high-level open access publishing is significant and on the rise. Consequently, in order to address these challenges, the committee recommends to stress the importance with the board of NWO-I to get NWO-I included in national transformative agreements. This is perceived as crucial for sustaining the economic model associated with open access publishing and ensuring long-term viability.

During the last strategic period, AMOLF started a data management policy aimed at the storage and publication of data following the FAIR principles. Important aspects of this policy concern the careful use and storage of logbooks, formulation of clear data management plans for every research group which lays out how data are acquired and stored, and the creation of a data replication package for all publications of AMOLF for which this is reasonably possible. The committee applauds the institute’s attention for and organization of data management practices. Besides its policy, significant attention is paid to replication packages including data, metadata, and logbooks that underlie scientific output. Regular training and informative workshops are provided to AMOLF and ARCNL researchers to instruct them how to store data and how to make these data publicly accessible in replication packages. Research groups can choose different electronic logbooks, creating an administrative burden for support staff. Workload of support staff is under pressure, see also chapter 3.5. The committee advises to review practices (e.g., various different types of logbooks) and work towards more standardization. NWO-I can play a role in advising and sharing “good practices” between institutes.

3.5 Viability

The committee considers the viability of the institute to be very good, both with regard to its financial stability as to its mission, strategy and concrete strategic actions. The committee fully supports further development of the three research themes, acknowledging their scientific value and alignment with AMOLF’s strengths. However, AMOLF’s story-telling considering the research themes can be improved. The committee found the broad descriptions of the themes in the self-evaluation report rather vague; the broad descriptions of the themes could be strengthened with additional compelling elements. In contrast, the presentations during the site visit were of a different nature. Research groups presented impactful and captivating stories about their projects and societal impact. The committee was particularly impressed by

the compelling examples spanning from blue-sky research all the way to (societal) impact. Therefore, the committee recommends to invest in developing compelling narratives and stories per research theme.

AMOLF wants to continue playing an important national role in initiating and developing research directions that are new to the Netherlands. The institute has demonstrated its capability in this regard. To maintain this ability, the committee recommends to create capacity, possibly through attracting “super postdocs” that can partially be supported by, but are not fully bounded to, particular projects. These multi-functional generalists, that do not specifically have a career path as group leader in mind, can quickly respond to new ideas in an agile manner, for example through conducting specific research tasks like quick test experiments. These researchers can fulfill various roles and can contribute to stabilizing research group sizes. Flexible funding to create capacity will further enhance the institute’s capacity to quickly react on potential research opportunities.

AMOLF has been very successful in obtaining grants from personal granting schemes. Through explicit policies including extensive tenure tracker monitoring and mentoring, critical proposal reading, and grant presentation ‘grill sessions’, AMOLF managed to extend this success to other grant types. As well, the basic infrastructure of AMOLF’s cleanroom facility NanoLab Amsterdam was renewed and strengthened as it was awarded funding in the National Growth Fund program. AMOLF’s strong policies, academic reputation, and position in (inter)national research programmes provide a solid base for its future financial viability. NWO-I base funding (direct funding) is essential in AMOLF’s financial security and viability. Base funding covers the salaries of scientific group leaders, group working budgets, start-up packages, most of the indirect and overhead costs, the technical infrastructure, and the building. Fluctuations in funding could highly influence AMOLF’s ability of initiating and developing new research in the field. The committee observed some reluctance in AMOLF’s relationship with NWO. This seems to be partially caused by a lack of transparency in NWO decision making processes, substantiated by similar boards of NWO and NWO-I.

Academic Culture

Promoting a scientific environment that is flexible, dynamic, and open, is a crucial aspect of the institute’s updated strategic plan. Collaboration and academic freedom play key roles in this plan. Working with a diverse team of researchers with mutual respect is described as essential to create an organization that is effective in performing creative, cutting-edge research, and that forms an inspiring and safe working place. AMOLF has taken different concrete measures to enhance social safety, inclusivity and research integrity. These include a number of activities to foster personal interactions, ease on-boarding of new employees, and ensuring that international employees feel at home. A notable institute-wide practice is the availability of both an internal and external confidential advisor. Staff seemed well-informed about the role and function of the confidential advisors. As the internal confidential advisor is a group leader, AMOLF considers installing a second internal confidential advisor. The committee recommends to do so, potentially from the support staff division. The committee also commends the responsibilities and activities of the integrity officer, along with the implementation of mandatory and recurrent training sessions.

In the conversations with staff members, the committee learned that AMOLF managed to create a welcoming and inclusive environment. The extensive onboarding process, focus on mentoring, and open-door policy contribute to a collaborative and open atmosphere. AMOLF’s flat organizational structure with short communications lines housing relatively small research groups, does indeed stimulate the interaction and collaboration within and between different research groups. There is a strong sense of community and equivalency. Individual staff members are dedicated to contributing to the collective effort and genuinely willing to assist and support one another. The committee applauds AMOLF’s efforts to share knowledge.

There are lots of opportunities to communicate formally and informally, these include both big picture and content-specific events, including poster presentations.

Human Resources Policy

Talent recruitment and management is an essential pillar in achieving AMOLF's national role. AMOLF strives to be an outstanding and attractive place for tenure track group leaders and aims to offer an optimal environment for research and training. Tenure track group leaders receive intensive mentoring by senior group leaders and there is a multi-step tenure track policy, start-up packages, and support in place. Significant effort is also put in the attraction and mentoring of PhD students, substantiated by AMOLF's PhD and postdoc training program. In conclusion, the committee is impressed by AMOLF's recruitment and mentoring efforts.

In the conversations, tenure track group leaders expressed to be very satisfied with their positions in terms of support, mentoring, and academic freedom. The committee discussed the length of the tenure track and assessment procedure. Despite the clear communication, policy, and strong support system during the evaluation procedure, the evaluation moments still cause stress. The longer duration of the tenure track offers some job security for an extended period of time (compared to short term contracts) and provide tenure track researchers with opportunities to establish ambitious research groups and independent programs. However, the committee suggests that AMOLF considers making tenure decisions earlier in the tenure track trajectory and considers reformulating it into a "career track" to reduce stress. Additionally, it recommends staying informed about university practices and align their tenure track trajectory accordingly.

At the moment, AMOLF tenure trackers typically become affiliated with a Dutch university within a few years after getting tenure. The committee expects it to be beneficial to become affiliated to universities in an earlier stage of their career. Tenure track affiliations with universities are not only beneficial to tenure trackers in achieving their future career goals, but also vital for AMOLF's mission to create outflow opportunities and for the supervision of PhD students. The committee advises to include university affiliations in AMOLF's multi-step tenure track policy.

Throughout the site visit, it became evident to the committee that the technical support staff is dealing with high workloads. In the past three years alone, no less than 19 technical and facility staff members have departed AMOLF. This not only places a substantial burden on the institute in terms of training new personnel, it also involves a considerable amount of time to fill these positions. The competition for talent and specific expertise is fierce. With six support staff members moving on to other knowledge institutes or universities (the other 13 support staff members continued their careers in the private sector), it became clear that AMOLF is not just competing with the private sector. Simultaneously, writing and coordinating increasingly large collaborative grants and programs require specialized and trained support staff. The committee emphasizes the importance of support staff and training as a requirement for AMOLF's success. To enhance support staff capabilities, the committee recommends to hire a specialized staff member for intellectual property (IP) support and training. In light of the institute's success, the committee urges the management team to explore possibilities to make positions more appealing, including sabbatical, training programmes, and attendance at symposia. Additional essential steps include setting up a valorization team and hiring a project officer actively identifying and reaching out to industrial partners and assisting in the evaluation of IP opportunities.

Diversity

The committee especially applauds the institute's inclusivity and diversity efforts. AMOLF's ambition for diversity and inclusion are described in the newly developed Diversity and Inclusion Plan 2022-2026 which builds on the Gender Equality Plan 2018-2022. AMOLF is a true leader and goes beyond what's mandated. Its broader policy regarding inclusivity and diversity got national recognition from the Netherlands' Physical Society (NNV). For the purpose of a more general promotion of diversity and inclusivity, a highly active and broadly supported Inclusivity and Diversity Team (IDT) was established.

In the interviews with AMOLF delegations, a wide variety of efforts have been highlighted in terms of female talent, managerial focus on gender policies, and tackling hidden biases. Management is aware that changes were and are required and action is taken. The committee acknowledges these efforts, yet concurs with the institute that there is significant room for improvement. AMOLF's target of a 25% representation of women among scientific group was not reached. Among some of the technical staff divisions, gender is even more unbalanced and far from the wished female representation. The committee is impressed by the exceptional female talent at the institute and recommends that the institute increases its efforts to actively seek opportunities for female scientific leadership, such as research theme leaders and directors. Like many other institutions, AMOLF is experiencing the 'leaky pipeline' effect, where a higher proportion of women men leave the academic system at each career step. While this is not unique to AMOLF, the committee advises to examine what measures can be taken to establish a more equitable level player field, addressing factors like housing and perceived job security.

PhD Policy and Training

AMOLF strongly focuses on high-quality training of their PhD students. Key aspect of its PhD policy and training is its high-level mentoring program including annual performance interviews, and well-communicated, clear and regular mentoring moments throughout the PhD period to evaluate plans and achievements. New initiatives focus on mental health, work happiness, and career guidance, including a 'buddy system' for newly arrived students, social and academic activities, and orientation activities on students' future careers. During the site visit, the committee met with an enthusiastic group of talented PhD students. Students feel welcome and respected and show specific appreciation for the safe, collaborative, and supportive environment created by the institute.

AMOLF PhD students receive their degree from a Dutch university. As a result, PhD candidates have to comply with various norms and regulations set by the different universities, for instance regarding courses they take. PhD candidates always have a supervisor in their team who is a professor at the university where the student defends their thesis. PhD students described the affiliations as the best of both worlds, in terms of available courses, networking opportunities, and facilities. However, students also highlighted certain challenges. In case the PhD student's group leader holds a tenure track position and is the daily supervisor of the PhD student, it might cause difficulties. Since tenure trackers do typically not have the *ius promovendi*, the group leader cannot be the promotor, and at some universities, they may only serve as an external advisor rather than an official member of the supervision team. This raises ethical concerns regarding supervision and promotion rights and introduces uncertainty for PhD students. In some cases, the official promotor was only found later in the PhD trajectory, causing unnecessary stress and unclarity for students. This also meant that students had to comply to norms and regulations set by universities in a later stage of their trajectory. PhD students also expressed that requirements from their affiliated university are not always clear. The committee concludes that it is crucial that PhD students know from the start of their trajectories at which university they will graduate and which specific requirements apply to them. Subsequent changes should be minimized and carefully managed, occurring only on an incidental basis. The committee recommends AMOLF to actively oversee PhD students' trajectories, including monitoring students progress

in fulfilling university-specific requirements, milestones, and facilitating timely scheduling of interviews. Implications of students' affiliations should clearly be communicated at the very start of students' PhD trajectory. The committee encourages the institute to continue efforts to standardize PhD trajectories, with a focus on streamlining and monitoring course requirements and completion. Establishing a PhD council could be beneficial to identify and address issues relevant to the PhD community.

The duration of an average PhD period at the institute takes 56 months between the start of the PhD and the defense. The indicated PhD periods include the administrative time delay between finishing the manuscript and the actual PhD thesis defence, which amounts to an average of 3-4 months. The committee sees room for improvement and strongly advises the institute to target 48 months as the PhD duration, ideally including the defense. The '18 months till PhD manuscript submission' and 'planning and evaluation' interviews are beneficial in guiding timely completion. However, the committee suggests improving the coordination and scheduling of these interviews for further efficiency.

4. Executive summary

4.1 Conclusion

The institute's mechanistic and quantitative approach and the three newly determined research themes create an excellent position and distinctive niche in the (inter)national field of natural and human-made functional complex matter. The research themes are strategically well-chosen, scientifically exciting and connect the institute's research groups in a novel way. The committee is particularly impressed with AMOLF's scientific output, covering the entire spectrum from curiosity-driven fundamental research all the way to industrial and societal impact. The institute profits of highly active and extensive networks of societal and industry partners in diverse fields of expertise. Among other thing, this results in remarkable success in organizing and coordinating complex consortia that extend beyond individual institutions and partners. AMOLF has a welcoming, collaborative, and inclusive academic culture, promoting a scientific environment that is flexible, dynamic, and open, which is a crucial aspect of the institute's updated strategic plan. The institute works hard on increasing diversity among all AMOLF employees, harmonizing PhD and data management practices, and optimizing recruitment and training practices. The institute houses outstanding group leaders, highly trained and valuable technical and support staff, and excellent facilities in terms of labs and equipment.

AMOLF shows strong commitment to fulfil its national role as an initiator and incubator of research directions that are new to the Netherlands, and that usually develop into larger national research programs. To continue to do so, AMOLF must continuously invest in a diverse, collaborative, and supportive research environment. This includes, among other thing, optimal support systems for its PhD students, reducing workload for (technical) support staff, and creating optimal career paths for tenure track group leaders.

4.2 List of recommendations

1. Develop clear schematic overviews illustrating how the five expertise centers are embedded into the institute and how leadership within AMOLF is structured.
2. Mobilize NWO-I for broader inclusion in national transformative agreements.
3. Invest in developing compelling narratives and stories for each research theme.
4. Create capacity, possibly through attracting multi-functional generalists or "super postdocs", to quickly respond to new ideas and potential research opportunities in an agile manner.
5. Install a second internal confidential advisor, potentially from the support staff division.
6. Consider making tenure decisions earlier in the tenure track trajectory and consider to reformulate it into a "career track" to reduce stress. Stay informed about university practices and align tenure track trajectories accordingly. Additionally, consider including and/or enabling university affiliations in AMOLF's multi-step tenure track policy.
7. Enhance (technical) support staff capabilities.
8. Continue efforts regarding (gender) diversity. Actively seek opportunities for female scientific leadership, such as research theme leaders and directors.
9. Actively oversee PhD students' trajectories, including monitoring students progress in fulfilling university-specific requirements, milestones, and facilitating timely scheduling of interviews. It is crucial that PhD students know from the start of their trajectories at which university they will graduate and which specific requirements apply to them. Additionally, target 48 months as the PhD duration, ideally including the defense.

Appendix 1: SEP Questions Evaluation NWO institutes

The 3 main criteria:

1. Research quality:

- How does the assessment committee assess the scientific quality of the institute, in light of its own aims and strategy? Central in this assessment are the contributions to the body of scientific knowledge. The assessment committee is asked to reflect on the quality and scientific relevance of the research. Finally, the academic reputation and leadership within the field is assessed. Looking ahead into the future, which recommendations can the committee give to the institute regarding their research quality?
- How does the committee assess the institute's place in the national and/or international research landscape? Is the institute a frontrunner or a follower in its field? Does the committee see untapped opportunities?

2. Societal relevance:

- How does the committee assess the societal relevance in terms of impact, public engagement and uptake of the institute's research in economic, social, cultural, educational or any other terms that may be relevant? The assessment committee is asked to reflect on societal relevance by assessing an institute's accomplishments in light of its own aims and strategy. Looking ahead into the future, which recommendations does the committee have for the institute regarding its societal relevance?

3. Viability:

- How does the committee assess the extent to which the goals for the coming six-year period remain scientifically and societally relevant? It is also asked to assess whether its aims and strategy as well as the foresight of its leadership and its overall management are optimal to attain these goals. Finally, the assessment committee is asked to assess whether the plans and resources are adequate to implement their strategic plan. The assessment committee is also asked to reflect on the viability of the institute in relation to the expected developments in the field and societal developments as well as on the wider institutional context of the institute.
- How does the committee assess the way the institute fulfills their national role and does the committee have any recommendations regarding this?¹
- How does the committee assess the way the institute contributes to the vision on 'Dutch research in 2030' as is written down in the NWO Strategy 2023-2027 and does the committee have any recommendations?

¹ With respect to the reports from the PCNI, the portfolio committee and (where relevant) the exploration reports.

In addition there are also 4 important aspects contributing to the success of the institute:

4.1 Open Science

The assessment committee is asked to consider to which extent the institute opens up its work to other researchers and societal stakeholders in the context of its strategy and policy. Furthermore, the committee is asked to consider whether the institute reuses data where possible; how it stores the research data

according to the FAIR principles; how it makes its research data, methods and materials available; and when publications are available through open access. The committee is specifically asked to give the institute and NWO-I recommendations on their Open Access and FAIR data and software policy. The assessment committee is asked to reflect on the current policies, and the practices with regards to the open availability of the publications, research data and methods and assess them in light of NWO's high ambitions (e.g. is the institute a frontrunner in its field with regard to Open Access and FAIR data and software?).

4.2 PhD policy and Training

- The assessment committee is asked to consider the supervision and instruction of PhD candidates. Furthermore, the committee is asked to consider whether the quality assurance system is functioning properly. The committee is asked for recommendations on how to enhance the supervision and education of PhDs (together with the universities), also in light of the three main criteria.

4.3 Academic Culture

- *Openness, (social) safety and diversity & inclusivity:* The assessment committee is asked to consider the openness, (social) safety and diversity & inclusivity of the research environment. The assessment committee is also asked to evaluate the actions and plans for the future of the institute with regards to (social) safety, diversity & inclusivity.
- *Research integrity:* The assessment committee is asked to consider the institutes policy on research integrity as well as the way the institute facilitates the relevant actions and requirements formulated in the Netherlands Code of Conduct for Research Integrity. For both themes: Looking ahead into the future, which recommendations does the committee have for the institute regarding their academic culture, also in light of the three main criteria?

4.4 Human Resources policy

- *Talent Management:* The assessment committee is asked to consider the institute's policies on talent selection and development in relation to its aims and strategy. More specifically, it is asked to evaluate the institute's recruitment policies, opportunities for training and development, coaching and mentoring, as well as career perspectives for researchers and research support staff in different phases of their career. An important aspect of this is the (inter)national cultural change regarding recognition and rewarding in academia that NWO-I is implementing. What are the institute's plans to further the desired cultural change and which recommendations does the committee have for the institute and NWO-I?

Appendix 2: Programme of the site visit

10 December (Location: Hotel in Amsterdam)

17.30 – 18.00	Welcome by AMOLF
18.00 – 18.15	Opening and interview with Prof. Marcel Levi, NWO
18.15 – 19.00	Preliminary meeting committee
19.00 – 21.00	Dinner and preliminary meeting (continued)

11 December (Location: AMOLF)

9.15 – 9.30	Closed session panel
9.30 – 10.15	Introduction to AMOLF and interview with the directorate
10.15 – 10.30	Coffee break
10.30 – 11.30	Research theme <i>Information in Matter</i>
11.30 – 12.15	Tour of the premises: Living Matter Lab, Modern Mechanics Lab and Nanophotonics Lab
12.15 – 12.45	Lunch
12.45 – 13.30	Tenure Track group leaders
13.30 – 13.45	Closed session panel
13.45 – 14.45	Research theme <i>Sustainable Energy Materials</i>
14.45 – 15.00	Coffee break
15.00 – 15.45	Heads of the Support Division
15.45 – 16.20	AMOLF NanoLab cleanroom and precision manufacturing department
16.20 – 16.50	Highlighted Narratives: Lumetallix and Growth Fund SolarNL
17.00 – 18.00	PhD Students
18.00 – 18.30	Postdocs

12 December (Location: AMOLF)

8.45 – 9.00	Closed session panel
9.00 – 10.00	Research theme <i>Autonomous Matter</i>
10.00 – 10.15	Coffee break
10.15 – 10.45	Directorate and MT: Data management, Open Science, PhD program, Scientific integrity
10.45 – 11.00	Confidential advisor and research integrity officer
11.00 – 11.30	AMOLF Inclusion & Diversity Team + female scientists
11.30 – 11.45	Closed session panel
11.45 – 12.30	Institute Advisory Committee
12.30 – 13.15	External stakeholders
13.15 – 14.00	Lunch
14.00 – 17.00	Internal deliberation of the committee
17.00 – 18.00	Presentation of preliminary results of the site visit to AMOLF
17.15 – 18.15	Drinks and dinner

Appendix 3: Quantitative data

Quantitative data on the institute's composition and funding, as described in SEP Appendix E, Tables E2, E3 and E4:

Staff

	2017		2018		2019		2020		2021		2022	
	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE
Tenured group leaders	12	11,5	12	11,5	13	12,5	13	12,5	15	14,5	16	15,5
Non-tenured group leaders	5	5,0	6	6,0	4	4,0	4	4,0	4	4,0	3	3,0
Postdocs	27	26,9	18	17,6	19	18,6	18	17,4	14	14,0	23	22,9
PhD students	49	47,8	59	58,0	59	57,8	56	55,8	63	62,8	65	64,8
Undergraduate students	23	20,3	20	18,7	27	26,2	29	25,4	27	25,9	24	21,3
Visiting fellows	7	0,9	8	1,1	10	1,4	10	1,3	7	0,8	5	0,7
Guests	18	6,9	20	9,0	22	9,2	18	7,8	28	11,7	27	10,8
Total scientific staff	141	119,3	143	121,9	154	129,6	148	124,2	158	133,7	163	138,9
Technical support	36	34,7	36	34,9	33	31,3	35	33,6	36	34,1	40	8,8
General support	40	32,1	36	29,1	36	29,0	39	30,5	34	27,6	35	28,9
Support staff ARCNL	12	10,2	13	11,6	13	11,4	13	11,7	14	12,8	13	11,2
Total support staff	88	77,0	85	75,6	82	71,7	87	75,9	84	74,5	88	79,0
Total Staff	229	196,3	228	197,5	236	201,3	235	200,1	242	208,2	251	217,9

Funding

Total funding and expenditure in k€ per year over 2017-2022

	2017		2018		2019		2020		2021		2022	
Base funding ¹	9.167	59%	9.757	62%	9.931	64%	10.412	62%	10.475	64%	10.800	58%
Research grants national ²	3.179	21%	2.992	19%	2.743	18%	2.783	17%	2.181	13%	2.904	16%
Research contracts other ³	3.083	20%	2.909	19%	2.840	18%	3.538	21%	3.032	18%	4.391	24%
Other ⁴	73	0%	8	0%	24	0%	3	0%	709	4%	393	2%
Total funding	15.502	100%	15.666	100%	15.538	100%	16.736	100%	16.397	100%	18.488	100%
Personnel costs	10.587	70%	10.204	70%	10.460	70%	10.563	71%	10.632	72%	11.616	69%
Material + Other costs	4.602	30%	4.278	30%	4.505	30%	4.332	29%	4.038	28%	5.339	31%
Total expenditure	15.189	100%	14.482	100%	14.965	100%	14.895	100%	14.670	100%	16.955	100%

Note 1: Direct funding NWO-I (base funding/ lump-sum budget)

Note 2: Research grants obtained in national scientific competition (e.g. grants from NWO and KNAW).

Note 3: Research contracts for specific research projects obtained from external organizations, such as industry, governmental ministries, European organizations, and charitable organizations.

Note 4: Funds that do not fit into the other categories (specific covid-related funds: 2021 +700 k€; 2022 +334 k€).

PhD candidates

Duration of the PhD period of AMOLF PhD students until the date of graduation (the indicated PhD periods include the administrative time delay between finishing the manuscript and the actual PhD thesis defense, which amounts to an average of 3-4 months).

Starting year	2014	2015	2016	2017	2018	2019	2020	2021	2022
Enrolment male	7	6	12	8	13	13	10	14	9
Enrolment female	3	6	8	2	7	4	4	7	8
Total	10	12	20	10	20	17	14	21	17
Graduated in 4 years or less	0	0	0	2	0				
Graduated between 4-5 years	6	6	15	8	8				
Graduated between 5-6 years	4	4	1	0	0				
Graduated after 6 years	0	2	0	0	0				
Not yet finished					11	15	13	20	17
Discontinued	0	0	4	0	1	1	1	1	0