AMOLF NEWS

SPECIAL EDITION

75 YEARS AMOLF

MAGICAL TIMES

AMOLF NEWS anniversary edition 75 years

This edition of AMOLF NEWS is a special publication marking AMOLF's 75th anniversary. It is a one-time issue. To stay updated, sign up for the AMOLF digital newsletter: amolf.nl/amolf-news-magazine.

AMOLF in short

AMOLF conducts leading research on the fundamental physics and design principles of natural and man-made functional complex matter. The institute applies this knowledge to create novel functional materials, and to contribute to the solution of societal challenges in renewable energy, green ICT, sustainable materials, and healthcare.

AMOLF is home to approximately 150 scientists working in 19 research groups. In addition, the institute employs 80 people working in technical and administrative support. It is located at Amsterdam Science Park. AMOLF is part of the institutes organization of NWO.•

Experiments for first AMOLF scientific paper: J. Kistemaker, H.L. Douwes Dekker, *Investigations on a magnetic ion source*, Physica, (1949).

Photo: AMOLF archive

AMOLF physics of functional complex matter

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Content

AMOLF NEWS

Magical times

I am proud and happy to introduce to you a very special issue of AMOLF NEWS that is completely dedicated to 75 years of magical times at AMOLF! AMOLF was founded as the 'FOM Laboratory for Mass Spectrography' on September 15, 1949, under the guidance of Jaap Kistemaker. In this AMOLF NEWS you will find an article by Ron Heeren on how the initial research of the institute developed into a large research effort on mass spectrometry and mass spectrometric imaging, with applications in biology, biophysics, art and medicine, also illustrating the societal relevance of AMOLF's research. In this magazine, our present research is also highlighted by a description of our research on information-processing materials, and by a fascinating example of our nonlinear nano-optical research.

AMOLF always had a highly dynamic research program, fulfilling its mission of initiating new research directions for the Netherlands. These dynamics would not have been possible without world-class technical support, providing the design and building of new scientific instruments, enabling completely new experiments. Our technical support is as dynamic as our research program, as is nicely illustrated in the interview with Hans Zeijlemaker and Isabelle Palstra, in which they tell about the start and development of our NanoLab cleanroom.

AMOLF has a long tradition of collaboration with university groups, other research institutes and industrial partners. An illustrative example of this is the recently granted National Growth Fund program 'SolarNL'. You will find an article in which Albert Polman explains how this large initiative was initiated and is coordinated by AMOLF.

Over a period of 75 years AMOLF has developed in many different directions and, inevitably, this AMOLF NEWS can only present a selection of the past and present. As for the future, I am convinced that AMOLF will keep playing a nationally and internationally leading role in initiating and developing new research directions, thanks to the highly interdisciplinary character of its research and the excellent support. In the coming years, new research directions will most certainly develop within the realm of the present three research themes on sustainable energy materials, information processing in matter, and on autonomous matter systems involving robots and living systems.
The longer term is hard to predict; I like to paraphrase the mission of the (Star Trek) Voyager:

"These are the voyages of AMOLF. Our ongoing mission: to explore new fields of research, to boldly go where no one has gone before."

Huib Bakker
Director AMOLF

Photo: Floris Krelage

Transmission Electron Microscope

Unique TEM installed

Sign up for the TEM symposium
amolf.nl/tem2024/registration-form

The climate crisis necessitates a shift to solar power, which requires a deep understanding of how light can be transformed into electricity, fuels, chemicals, materials, and heat. However, studies on how light affects matter at the atomic level are scarce.

A promising new microscope has recently arrived at AMOLF, which is expected to make a significant difference. Our unique TEM (Transmission Electron Microscope) allows researchers to not only observe materials at the atomic scale, but also to monitor changes over time under the influence of light. This means that materials can be studied under conditions much closer to those in real-world applications.

The TEM will be available for all researchers affiliated with one of the Dutch universities, research institutes or R&D departments of companies. The official opening of the facility will take place on October 11th. Make sure to not miss it and sign up before September 30th for the opening and symposium on Light-Driven Processes Monitored Inside the TEM.•

Alumni ☺ stay in touch!

AMOLF's current successes are built on the contributions of its alumni. This fall, AMOLF celebrates its 75th anniversary and of course our scientific and support alumni are invited to celebrate with us. They have been contacted to come to AMOLF on October 3rd for an afternoon and evening program.

Together with former colleagues, alumni can explore the latest AMOLF discoveries in both the lab and the lecture room or learn more about recent support projects. So far, 285 alumni have signed up! Registration is still possible at the events page on the **website**: amolf.nl/events/amolf-75-years-alumni-event.

To help stay connected with AMOLF and former collegues we have set up a **LinkedIn alumni group**. Are you a scientific or support alumnus? Join the LinkedIn group and connect with fellow alumni.•

Science Day October 5th

One of AMOLF's key events, formerly known as the Open Day, is now Science Day! Come visit us as the institutes at Amsterdam Science Park open their doors for an exciting dive into science on Saturday, October 5, 2024.•

Subscribe to AMOLF's

digital newsletter

Times are changing, and AMOLF is good at adapting. Therefore, this is our final printed magazine as we switch to a more sustainable online newsletter. Stay updated by signing up via the link below and join us in this new chapter!•

amolf.nl/amolf-news-magazine

UNRAVEL

we try to unravel
how proteins fold
how cells take control
and adjust to their role

we try to define
dynamics in time
of spontaneous shapes
pattern formation
in crystallization

we try to find rules
that molecules use
for function and growth
the local connections
for their interactions

we try to let go of
rigid ideas building
soft and small pieces
acting together
independently

we try and we try
until we might unravel
the marvel of life
and autonomous matter

Bauke Vermaas
Science writer and Zwolle city poet

Creating life
from lifeless biomolecules

"How simple can you make it, and still get something that can be called alive?"

Kristina Ganzinger

What if we could build life from scratch?

How does life emerge from lifeless molecules? To answer this question a consortium with three AMOLF research groups aims to build a living synthetic cell from lifeless biomolecules. "We want to know the magic ingredients to transition from non-life to life."

Text: Dorine Schenk • Photos Floris Krelage

All lifeforms consist of cells, which consist of molecules. Cells are alive, but their building blocks, the molecules, are not. How does a living cell emerge from lifeless molecules? And what are the minimal components you need? The answers to these questions are fundamentally relevant and can also lead to applications, like drug testing and cost-effective immunotherapy.

"From studying living cells we know a lot about their main ingredients", says Pieter Rein ten Wolde, group leader of Biochemical Networks at AMOLF. "We know how DNA is duplicated, and proteins are made, for example. But how all components come together to form a cell that can grow and divide autonomously: that is still an open question."

To answer these questions a multidisciplinary team of Dutch scientists, with three AMOLF research groups and led by TU Delft, aims to build a living synthetic cell from lifeless biomolecules. This ten-year research program, called 'Evolving life from non-life' or simply 'EVOLF', was awarded a million euro Summit Grant by the Dutch Research Council (NWO).

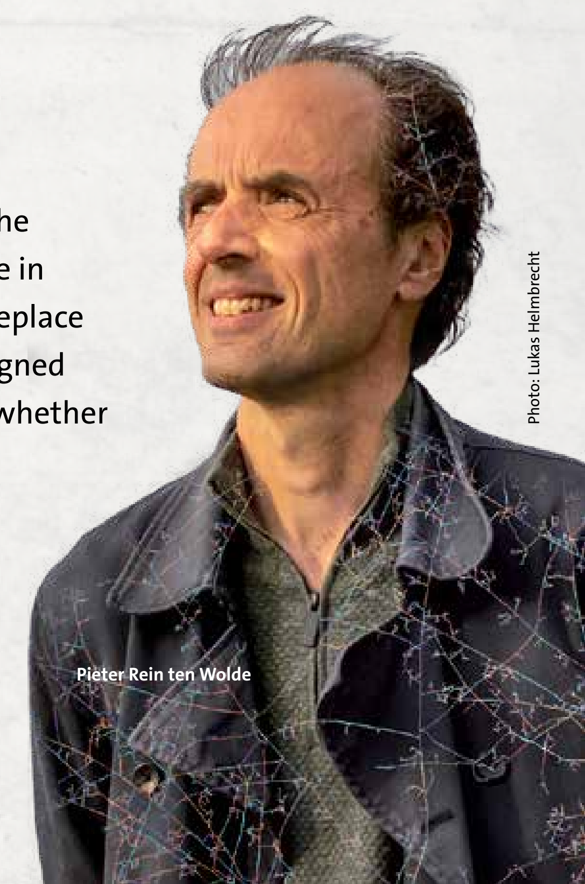
The three AMOLF research groups that are involved are led by Sander Tans, Pieter Rein ten Wolde and Kristina Ganzinger. Sander's and Kristina's research groups work on developing sensing and communication between synthetic cells and with their environment. Pieter Rein's research group works on integrating all individual cellular functions into one unified synthetic cell.

Creating a synthetic living cell, might sound like a Frankenstein-project. Because of the ethical implications, there arephilosophers and humanities scholars involved in EVOLF. They will make the connection with philosophical and ethical research and work on responsible research guidelines to establish conditions where humans remain in control of synthetic life.

Designing cells

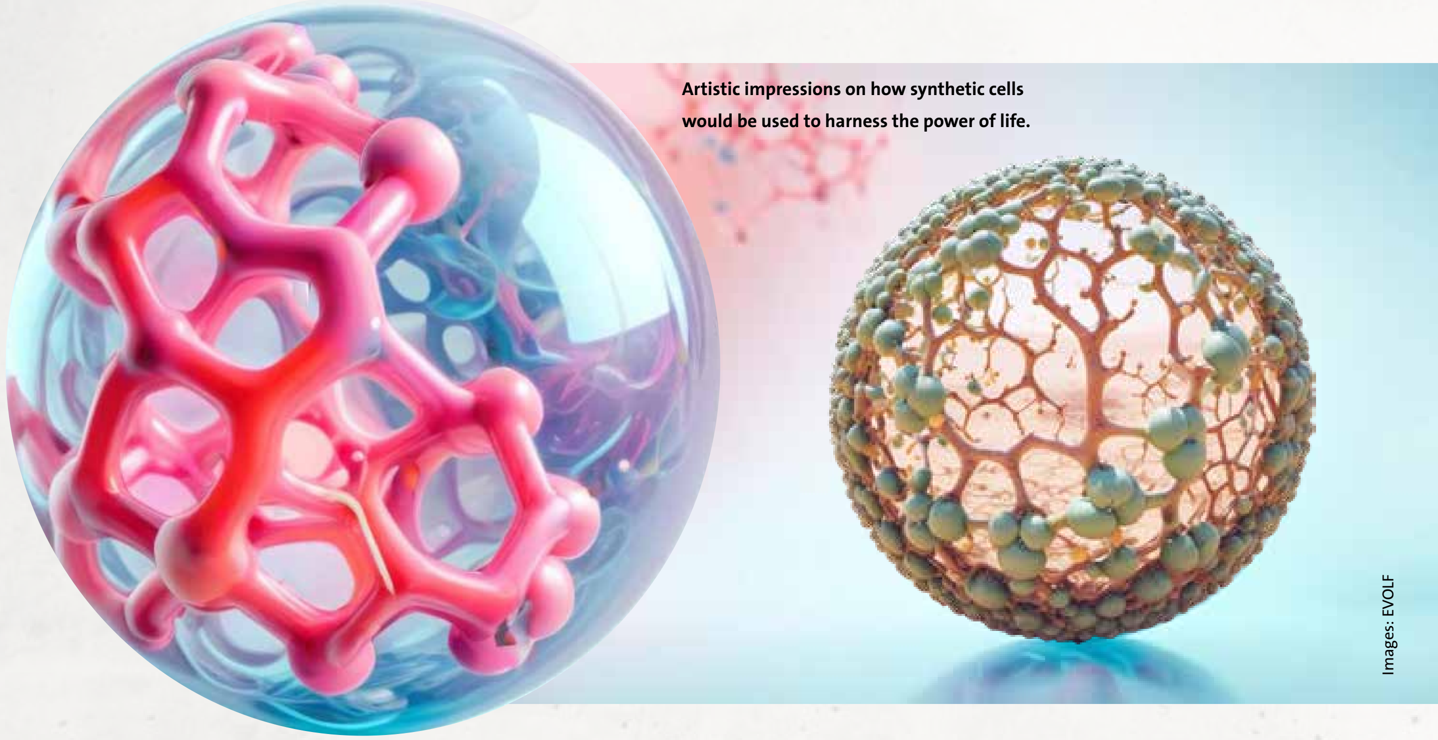
The EVOLF-scientists build on earlier work done in the Dutch research consortium BaSyC. "Our next step is the transition from non-life to life", says Kristina Ganzinger, group leader of Physics of Cellular Interactions at AMOLF.

We knock out the existing module in the *E. coli* and replace it with our designed module to see whether it works.



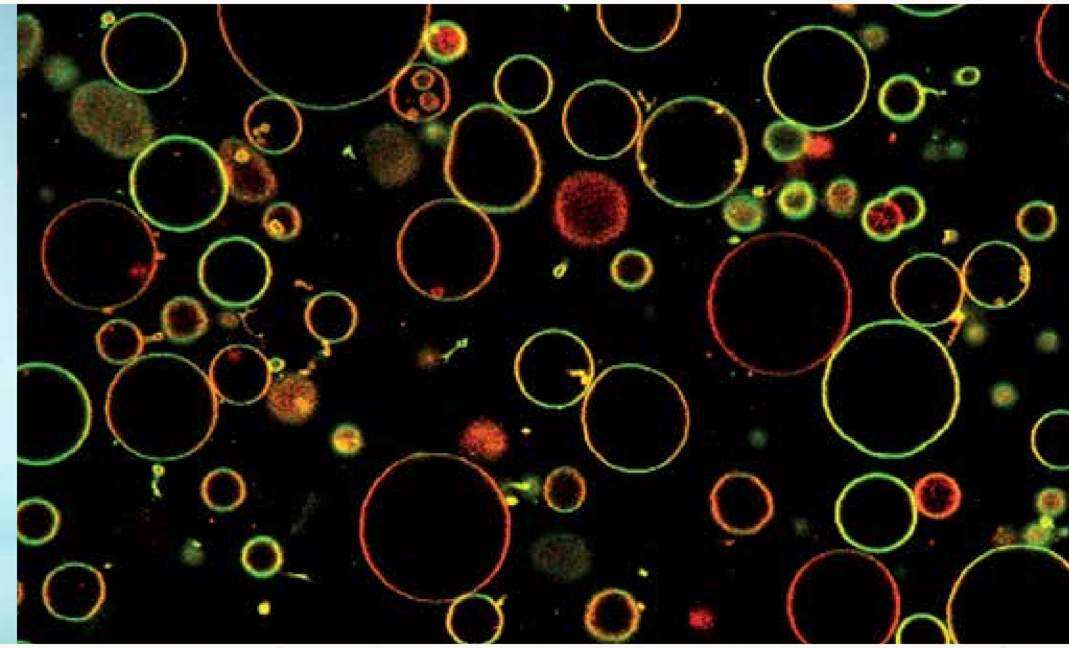
Pieter Rein ten Wolde

Photo: Lukas Helmbrecht



Artistic impressions on how synthetic cells would be used to harness the power of life.

Images: EVOLF



Immune synapse
T cell (green) making contact with cancer cell (red); Receptor dance: spatiotemporal organization of CARs (therapeutic T cell receptors) at model immune cell-tumour cell interfaces.

"For a living synthetic cell, we need proteins which get food from the environment and turn that into ATP – which is the fuel that internally drives processes within cells. And we need proteins that allow the cell to duplicate its DNA and divide", says Pieter Rein. "And all these processes have to come together to create a cell that can self-replicate."

The scientists will not copy every detail of a real, living cell to make a synthetic duplicate. They take another approach. "We want to know which components are minimally required and how they should be wired to establish a living cell", explains Ganzinger. "How simple can you make it, and still get something that can be called alive?"

"What is minimally required? That is the type of question that physicists love", says Pieter Rein. "In EVOLF we get to answer it in the context of life by starting with building a minimal cell and from that, study how different cells interact and form more complex structures. This is the physics approach to how life works."

Borrowing from nature
How do you build a synthetic cell? "We start with synthetically made lipids that we use to make liposomes, which are spherical-shaped vesicles that resemble cell membranes", says Kristina. "Then we add the genome that encodes the proteins that carry out vital cellular functions, such as cell division, DNA replication, and fuel processing. We do need to borrow one component from a living cell to jump start the newly built cell: ribosomes." Ribosomes are molecular machines that translate genetic code into proteins. They are critically important, but incredibly difficult to make.

To determine which proteins need to be encoded in the genome, the scientists design modules to make the cell function. "For example, we try to come up with a minimal metabolic network that has proteins that take a food molecule from the environment, import it into the cell and convert it – step-wise – into ATP", says Pieter Rein. "To do that we first design such a minimal network on paper. Then, we turn it into in a mathematical model to simulate it on a computer. Finally, we try to synthesize these proteins in the lab and bring them together to see whether they indeed form ATP."

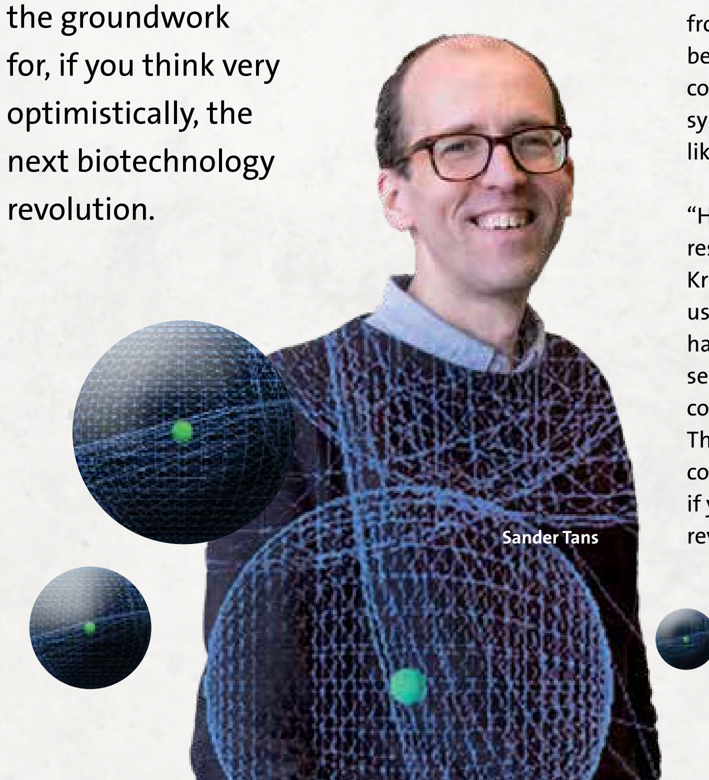
The same process is done for other modules, like the one that controls cell growth and self-replication. "Some of those modules cannot be tested independently", says Pieter Rein. "To test them we use an *E. coli* bacterium. First, we knock out the existing module in the *E. coli* and replace it with our designed module to see whether it works."

When all modules work, they must be combined. Pieter Rein: "We are now at a stage where quite a few individual modules – but not all of them yet – work. The main challenge in the coming ten years will be to bring them all together."

Designing the cell cycle
Within the consortium, Pieter Rein's group is responsible for designing the so-called cell cycle. This is the control system that ensures that the DNA duplicates and the cell divides at the right moment in connection to cell growth. This is critically important to keep the volume and the DNA-density constant, so the cells will not become bigger and bigger, for example. Pieter Rein: "We design that in the same way as the minimal metabolic network."

Kristina's group works on cell-to-cell communication with a focus on the immune system. With high resolution microscopy they study how molecules in cell membranes self-organize to allow cells to talk to each other and to the environment. "In our research we move fluidly between existing living systems and synthetic systems", says Kristina. "We use that within EVOLF to work on methods for synthetic cells to detect and respond to their environment, like how natural cells communicate and interact with each other.

Our work could be the groundwork for, if you think very optimistically, the next biotechnology revolution.



Sander Tans

Photo: Mark Knight

Attacking cancer cells
These minimal synthetic cells could become useful for biotechnological or medical applications. They could, for example, improve cell-based therapies, like immunotherapy for cancer, where you give a patient cells that are genetically modified to attack cancer cells. Currently this requires cells from the patient. Kristina: "The synthetic cell could theoretically be a one-size-fits-all that would make this treatment more cost-effective and accessible." Another example is the use of synthetic cells to test how drugs affect cell functions, like division.

"However, it is important to know that this is fundamental research. AMOLF is a fundamental research institute", says Kristina. "I think that our reductionist approaches will enable us to understand living cells in a different way than we could have ever imagined. We could start to understand this ultimate self-organization of nature, how out of lifeless molecules complex structures form that we call cells and even tissues." That might not lead to new technologies in the near future, continues Kristina. "But it could be the groundwork for, if you think very optimistically, the next biotechnology revolution."•

An easy method to **detect lead**

with a spray and a UV lamp

It reads like a storybook. In 2021, fundamental research conducted at AMOLF formed the basis for the startup company Lumetallix. The company developed an easy to use and affordable method for the detection of lead. Two years later, Lumetallix has sold thousands of test kits and now has collaborations with scientists, NGO's and even forensic experts.

Text: Bastienne Wentzel • Photos: Floris Krelage

> "Firing a bullet from a gun releases a fine lead powder. Detecting the lead dust provides a lot of information about the shooting"
>
> Wim Noorduin

Help with crime scene investigation

Detect lead particles on the hands of anyone who fired a gun.

Improve the environment

Detect lead by improper recycling of batteries.

Save the children

One in three children worldwide suffers from lead poisoning.

It all started with a local tv program, where AMOLF researcher Wim Noorduin first heard of the dangers of lead exposure. From a study by UNICEF and Pure Earth—an NGO focused on lead poisoning—he learned that the problem of lead exposure is very large: one in three children worldwide suffers from lead poisoning from paint, piping, improper recycling of batteries and many other sources, affecting – among other things – their brain development.
At AMOLF, Wim and his colleague Lukas Helmbrecht had been working on the conversion of various compounds into lead-containing semiconductors. Linking his research with the problems addressed in the tv program, Wim took some of the reagents home to see if they would react with lead pipes in his house. If so, these would light up bright green under UV light. Disappointingly, in his home nothing lit up, but the lead roof cladding of the neighbors did and - to his surprise the windowsills also did. It turned out these contained lead paint. "They continued to shine for weeks!" recalls Wim.

The researchers realized they were on to something: an easy method to detect lead with a spray and a UV lamp. It could be used by anyone, including people living in less wealthy countries, who are at much higher risk of lead poisoning than we are, explains Lukas: "My drive has always been to empower people to test their environment themselves, so they can take action to avoid lead poisoning."

Scale-up

Lukas developed the chemistry, hijacking the technology from their semiconductor research. Soon, the test kit went up for sale on the Lumetallix website and the researchers provided kits to scientists to do their own projects. Then, the challenge was to find a way to scale up, says Wim. Only then can they reach their goals to raise awareness for the dangers of lead poisoning and to empower large groups of people to change their environment.
Getting in contact with Pure Earth and the Dutch environmental consultancy company Tauw, proved essential. Pure Earth set up a mission to India to try out different lead tests, including the Lumetallix kit and Lukas joined. "India has one of the largest populations of children with lead poisoning. Every second child is affected," says Lukas. The test worked perfectly in the less than perfect conditions of a monsoon drenched, polluted, wet, hot and bright climate. Previously, Pure Earth relied on expensive XRF measurements, which limits the number of tests that can be done.
The success resulted in a formal global collaboration with Pure Earth, which was signed in July. Lumetallix makes the kit available to their worldwide network and donates a portion of the proceeds to their mission. "NGO's have a very limited budget," explains Wim. "Only with this money that we contribute to them, can they scale up the roll-out of the lead detection kits and reach as many people as possible. For Lumetallix, scale is essential too."
"The circle is complete," Wim reflects. "The idea of developing a lead test started with the tv program and the

→

Lumetallix lead detection test kit

Lead is toxic and causes brain damage and cardiovascular damage, among other things. Young children are especially vulnerable. It is crucial to know if there is lead present in the living and working environment to take measures to avoid exposure. The Lumetallix test kit contains a non-toxic solution that you can spray on any surface, then shine on it with the supplied UV-flashlight. If your sample contains lead, you will see it emits bright green light. The lead in your sample forms lead perovskite with a component in the spray. Lead perovskite is a so-called luminescent material, which lights up bright green under UV light. The test kit is available globally through the Lumetallix website: lumetallix.com

Lucas Helmbrecht performing a lead test.

UNICEF and Pure Earth report, showing how many children are affected. Now these NGO's are rolling out our test exactly for those children."

Crime scene investigation

Remarkably, the researchers recently published a very different application for their test: in forensics. Wim explains: "We identified this as a potential interest from the beginning, but we were not sure how to do it. Until we contacted Arian van Asten. Working with Van Asten, a professor of forensic analytical chemistry at the University of Amsterdam (UvA), AMOLF researchers Kendra Adelberg , Arno van der Weijden and experts from the Netherlands Forensic Institute NFI and the forensic police, they investigated the possibilities to detect lead from gunshots.

Firing a bullet from a gun releases a fine lead powder from the explosive charge. Detecting the lead dust and especially the deposition pattern provides a lot of information about the shooting, Wim explains. "It can tell the police if the gun was fired from close by or from far away and from which direction. The pattern contains information on the rifling of the gun - the spiral grooves in the barrel. And the coolest thing: it can detect lead particles on the hands of anyone who fired the gun, even after they have washed their hands."

Lukas set out to adapt the lead test to fit the protocol that forensic researchers use at crime scenes. The researchers then got rare access to a firing range to try out the new test. "It was exciting, suddenly we moved from finding lead in household environments to being subjected to security and background checks," Wim smiles.

Fast and sensitive results

The results of the experiment were encouraging. Lead dust patterns are perfectly transferred to other surfaces, such as the structure of the original substrate, the shockwave pattern and the rifling pattern. The test is very sensitive because the lead particles are very small. "The smaller the better for our test, whereas in traditional analysis very small particles are a problem," according to Wim.

The forensic police is excited about the results, he says. "Our test is fast and sensitive and can be used to quickly get information after a shooting incident. The traditional analysis will still be done to confirm, for example, that a person did actually shoot, instead of just touched lead from another source. But this analysis is expensive and can take hours to days to get the results. It can even be too late to use in a court case."

The research will be continued by UvA and AMOLF, together with forensic experts at the police, NFI and laboratories in the USA. Together they want to make sure that what works in a controlled situation in the lab, also works flawlessly on the streets providing evidence in actual crime scenes.

Fundamental research, such as at AMOLF, may lead to an unexpected application. This is important to talk about, says Wim: "We often have to explain why we do this fundamental research. It's a valid question but this story shows that it is very important to do blue sky research. We never thought of all these applications when we started. I really appreciate how AMOLF has supported us throughout this process."•

"You can walk into any lab and literally touch the research"

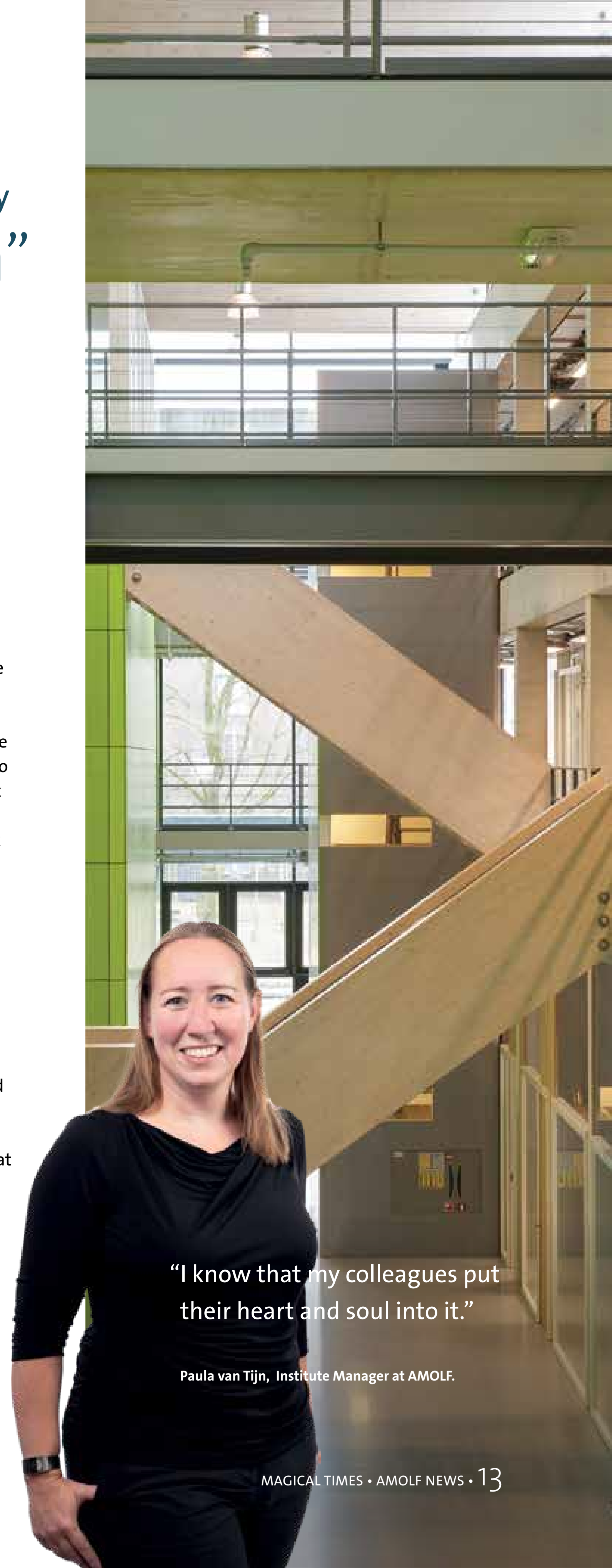
Text: Paula van Tijn

Fascinated by the way in which the brain works, I began my journey as a PhD student researching Alzheimer's disease. At the Netherlands Institute for Neuroscience, I gazed through a microscope at brain cells, analyzed the data and wrote it all down coherently in a doctoral thesis. To conduct this research I had a lab full of equipment at my disposal, a comfortable workspace and unlimited amounts of coffee. I thought this was normal and had no idea what was needed behind the scenes to run a scientific institute. Everything was always 'readily available'.

As Institute Manager at AMOLF, I now know that nothing automatically becomes 'readily available'. On the contrary, it is quite special that so many people – researchers and support staff – work together to make the institute a unique space where wonderful research can flourish. AMOLF stands for excellent science, innovative research themes and strategic collaborations. AMOLF is on its way to an outstanding future and I contribute to this in my role. How great is that! I think it is fantastic to be so close to experiments; you can walk into any lab and literally touch the research – although I think that nobody will be happy if I, as a neurobiologist, start touching experimental physics setups.

These setups are better with our technicians who know the labs like the back of their hands and who, together with technical support, have turned the design and construction of unique setups into an art form. Without consistent temperatures and air treatment, experiments can go tremendously wrong. But fortunately, we have Facilities to manage the complex technology running in the background ('you'll only see it when you've mastered it', as Cruijff used to say). And although I used to think as a PhD student that administration materialized with a single mouse click and IT infrastructure came from a socket in the wall, I now know that my colleagues put their heart and soul into it. They are sometimes less visible to the outside world, but they are indispensable.

My interest in the brain has not disappeared. Because of my work at AMOLF I have gained an additional fascination: how all departments at the institute – like our brain – are connected and together form an integrated network. The departments signal each other, the processes align, and wonderful AMOLF research is enabled.•



Paula van Tijn, Institute Manager at AMOLF.

AMOLF the **PhD Factory**

Training for a broad variety of jobs

In 1985 the Dutch magazine Vrij Nederland published a special issue ‘*De Promotie-fabriek*’ (the graduation factory), which reported on the research at AMOLF. Jannetje Koelewijn, a journalist with the magazine, spent several days at the institute to follow our daily life in the lab and wrote an outsider’s impression of PhD students doing research (‘*Vier jaar lang FOMmen op zoek naar de trillingen van het atoom*’).

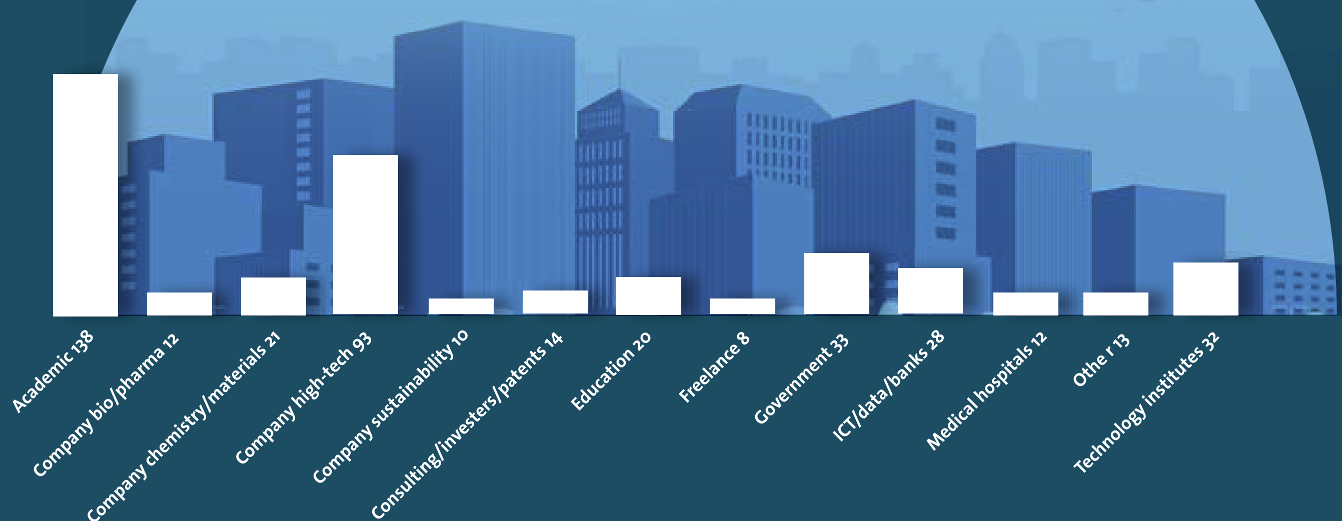
AMOLF was a research institute right from the time it was founded in 1949, initially research was done only by staff on permanent contracts. Over time, it became common for researchers to report their findings in a PhD thesis. The first PhD students on temporary four-year contracts were hired in the 1960s; the number of PhD graduations at the time was only a few each year. In the 1970’s, AMOLF became the *promotiefabriek* that it still is today:

- The number of PhD graduations strongly fluctuated over the years, with a peak in the period 2004-2010, some 25 graduations each year.
- Presently, 10-20 AMOLF PhDs graduate every year.
- Since the institute's founding, over 650 PhD theses have been completed describing research carried out at AMOLF.

As a *promotiefabriek*, AMOLF has played its role as an educational institute, delivering highly trained specialists that contribute to many aspects of our society. We have made an inventory of the jobs that former AMOLF PhDs have today, using mostly LinkedIn as source of information. We also investigated the present jobs of 434 active (not retired) former PhD students and found a very wide variety.

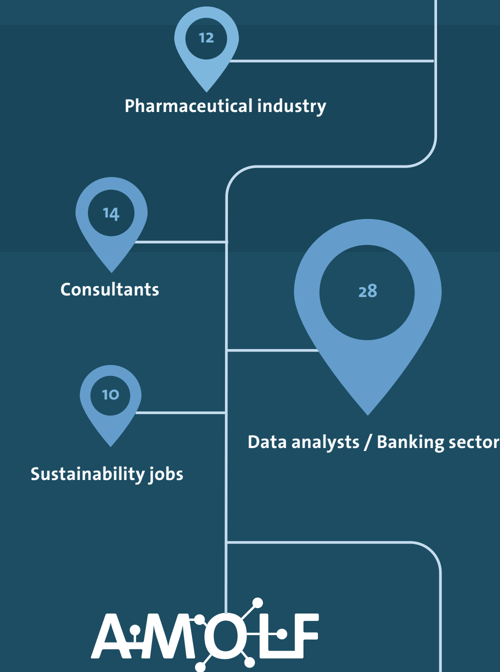
AMOLF alumni in companies

Many former PhDs have found a job in a company (150), mostly in the high-tech sector (93), but also in the chemical, materials, bio/pharma or sustainability industry. ICT, data analysis and banking companies are also well represented (28). ASML is the biggest employer, offering jobs to 26 AMOLF PhD alumni.



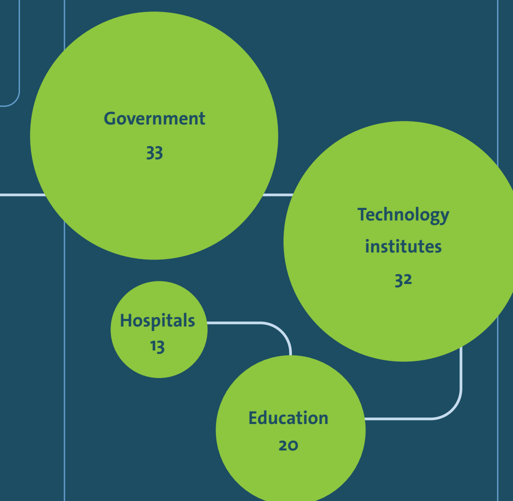
Changing career paths for AMOLF PhDs

As AMOLF’s research program has continuously evolved during the past decades, the jobs found by PhDs have also changed. The biophysics program that we started in the early 2000s has trained PhD students that now have jobs in the pharmaceutical industry. Trained with a broad range of skills, PhDs are also increasingly finding jobs as consultants, data analysts and in the banking sector. And AMOLF’s most recent program in sustainable energy materials increasingly leads to PhD students finding their way in sustainability jobs.



Other societal jobs

Our former PhDs also contribute to many other important aspects of society, having jobs with the government (33), and in technology institutes such as TNO (32), hospitals (13), education (20), and more.



Over 100 AMOLF professors worldwide

Many AMOLF PhDs (138) continued their career in academia. Several recent PhDs are now postdoctoral researcher, and some have permanent jobs as researchers at universities or other academic institutions. Quite amazingly, 82 former AMOLF PhD students are now professor at a university in the Netherlands or abroad! This includes assistant, associate, and full professors. They have professorships in the Netherlands, in countries all over Europe, and in the USA, Canada, India, Indonesia, Jordan, China, and Korea. Aside from the PhD careers analyzed here, many postdocs that worked at AMOLF became professors at universities all over the world as well. In addition, 15 of AMOLFs present group leaders are professor at a Dutch university.

Some PhDs have started a career far away from scientific research, we found some of them as e.g. a musician (a cellist), a farmer, and a mayor of a Dutch city. One former PhD went into a monastery and is now a priest.

Shared knowledge faster progress

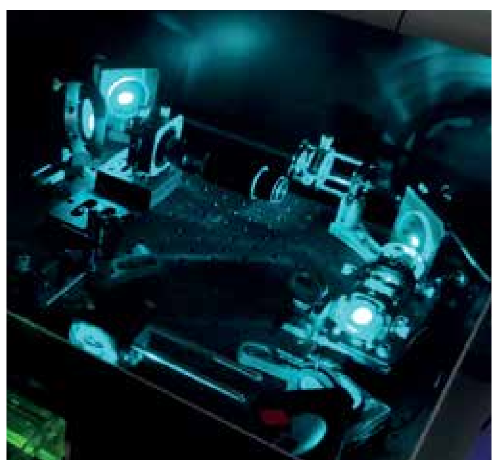
Building scientific instruments can involve reinventing the wheel. Researchers at AMOLF are changing that by adopting open-source principles for their single-molecule microscope, promoting collaboration and accelerating scientific progress.

Text: Kristina Ganzinger and Christian Niederauer

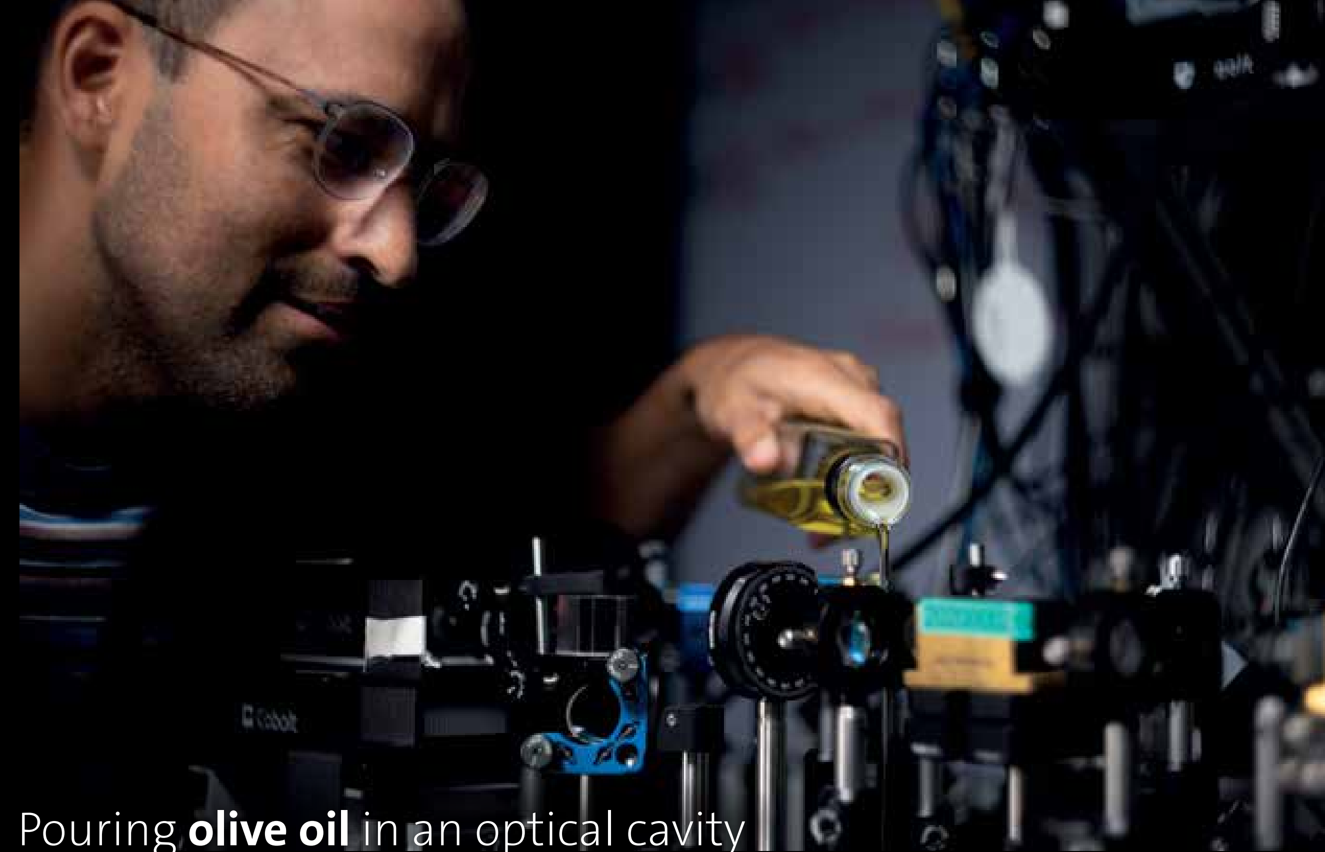
Antoni van Leeuwenhoek, the Dutch scientist had better microscopes than anyone else in the sixteenth and seventeenth centuries. Others assumed he had a very special, secret method of making his instruments, discouraging them from trying to replicate them. Only a few years ago, scientists studied Van Leeuwenhoek's microscopes with neutron tomography techniques and found he was merely exceptionally good at polishing his lenses into spherical shapes. Had past researchers known this, they probably would have been able to build microscopes that were equally good much earlier. So, by keeping his methods to himself, Van Leeuwenhoek inadvertently hampered scientific progress.

In today's single-molecule microscope community, things are very different. Since these microscopes are not available commercially, a lab typically hires a PhD student or postdoc to build one from scratch, reinventing the wheel every time. At some point, a critical mass of people in the community reached a consensus, saying: 'Let's do everything in the open and see if we can converge on some ideas, to save resources and money.'
Around that time, we started our Physics of Cellular Interactions lab at AMOLF, and we also chose the open science route for our own multi-color single-molecule TIRF microscope K2. We put up our plans for scrutiny before the microscope was built, talked to people about them during conferences, and documented the whole process from start to finish.
An integral part of this is GitHub, a platform where developers can store and share their code. We use this to put up our code so others can comment on it, reuse it, or improve it, and we benefit from code that others have published there. We also host a website at GitHub, where we share the design plans for our microscopes. On top of that, we published an article in an open hardware journal that has even more information on how to construct a setup like ours.

We believe that the ability to build upon each other's work is fundamental to scientific progress. Unfortunately, we have personally encountered the opposite, where we were unable to replicate certain methods due to insufficient information in the original publications. Being transparent and reproducible is also incredibly important for science beyond scientific instrumentation. By publishing data sets online, you allow other researchers to perform their own analyses starting from the same raw data, to see whether they reach the same conclusions as you. We enable this at AMOLF by having our researchers add so-called replication packages to their papers: sets of raw data others can use to reproduce all the plots in a publication.
One drawback of our approach to microscope development is that our instructions are primarily beneficial to laboratories with substantial experience in similar setups. Alternatively, we could have established a company to commercialize ready-to-use single-molecule microscopes, making them accessible to any institution with sufficient funds, regardless of expertise. Both strategies have merits and should coexist, but we think researchers should choose which one they take very early on. And if they decide not to commercialize their devices, being as open as possible with everything related to their technology is essential to avoid unintentionally obstructing progress, as Van Leeuwenhoek did centuries ago.•



Today's multi-color single-molecule TIRF microscope K2 (Simultaneous Triple-color total Internal Reflection Fluorescence).



Pouring **olive oil** in an optical cavity

A daring decision

Text: Bauke Vermaas • Photo: Floris Krelage

"Why don't you try olive oil?" It sounded like a joke, because Said Rodriguez was not asking for help in the kitchen. He had been trying to find the right material for his experiments in non-linear optics for over a year, but up until then all conventional materials had failed.
"So everybody laughed, but I got curious and dove into the literature," says the head of the Interacting Photons group. "I discovered that some oils were reported to have a refractive index that depends on the intensity of light, which was exactly the property we needed."

Said bought several different oils at the shop and put them in his optical cavity to test. "Immediately, we got the results we had been looking for," he remembers. "Because olive oil showed the strongest effect, we used it for many experiments in the following years. Lately, we have switched to cinnamon oil, however. Cinnamon oil turns out to be even more non-linear."

With oil as the cavity medium in optical experiments, Said and his group obtained many interesting and often surprising results that led to several excellent publications. For example, they realized photon superfluidity in a cavity filled with cinnamon oil. They also showed how to amplify signals using noise in a cavity filled with olive oil. But, six years after his first experiments, Rodiguez feels that most of the photonic community is not ready yet for oils. "Oils are cheap, non-toxic and have properties at room temperature that can uncover exciting new physics," he says. "But it still invokes laughter. And even if researchers know about the amazing optical properties of oil, they are discouraged to use them because oil is not solid. Liquids are messy and it is harder to integrate them in eventual applications."

Regular funding for science leaves very little room for out-of-the-box ideas, which made it hard for Said to get funding for follow-up research that is explicitly about using oil in optics. "Yet, I dare say that using oil as an optical medium was the single most important discovery for my group," says Said. "And, I could not have done this research if AMOLF had not given me the freedom to be creative when I started my group. Creativity requires not having a rigid plan. Being fluid can be risky, but also increases the chance of finding something really new."•

Continuous brainstorming about improvements is **inspiring**

Wessel Zwart

Alexander Evers

“**We quickly realized that a robot is ideal** for fully autonomous handling of 250 petri dishes.”

Text: Anita van Stel • Photos: Floris Krelage

A new setup with more petri dishes and at least six microscopes to take photos and videos. This was the request made by Physics of Behavior researchers Loreto Oyarte Gálvez and Tom Shimizu to the Mechanical Design Department.
Bas Steenbeek and Henk-Jan Boluijt are immediately interested. Together they involve colleagues from all other support departments to work on the project, which they name ‘Aretha’. The challenges range from ‘how to place a petri dish under a microscope’ to ‘where to store all the data.’ Together, they enthusiastically talk about the project, describing 'Aretha' as ‘typically AMOLF’: starting from scratch and ending with something unique in the world.

The research
Loreto and Tom study fungi. In the lab, these fungi grow from a compartment, in symbiosis with plant roots to a second ‘only fungal’ compartment. The researchers track the fungal network paths and how nutrients move through them. By adding fluorescent substances, they make the flow of nutrients visible. The fungal samples are made at VU Amsterdam and remain there in an incubator for one month before getting to AMOLF to be imaged. They have a scientific lifespan of several months. With their research, Loreto and Tom map out these naturally evolved systems, with a bigger question in the back of their minds: can these observed principles also be translated to designs outside of biology?

Scaling up
Bas, from the Mechanical Design department, talks about the initial request from Tom and Loreto: “Their drive was to collect much more data in a shorter time. This could be achieved by getting more samples in and out of a microscope faster. Another wish was to zoom in with a video microscope to see how substances flow through the fungus. Currently, Tom and Loreto use a setup, which holds 40 petri dishes and one microscope to photograph the fungi at low magnification. They use a different setup to manually record high magnification videos of flows in the fungi. With the desired scale up, the videos could be fully autonomously controlled, based on data from the photos. In a controlled environment with hundreds of samples at once.”

Marco Seynen

Cees van der Ven

“**We needed a new setup** with more petri dishes and at least six microscopes to take photos and videos.”

The design
Bas: “At first, we thought of a train system or a rotating carousel. We quickly realized that a robot is ideal for fully autonomous handling of the petri dishes. Simulations showed that a robot could handle 250 dishes.” The designers and researchers decided that ‘Aretha’ should be a setup consisting of four photo microscopes, two video microscopes, and a rack with 250 dishes. They devise an enclosed lab space with a ‘mailbox’ as a hatch. In the adjacent room, a researcher can place or remove a sample through the mailbox. The robot receives a signal, picks up the petri dish from the mailbox, places it under the microscope, and returns it to the rack. The sample remains in the setup until its lifecycle ends. Or, if the sample is no longer in good condition, the researcher is notified to adjust or remove the dish through the mailbox.

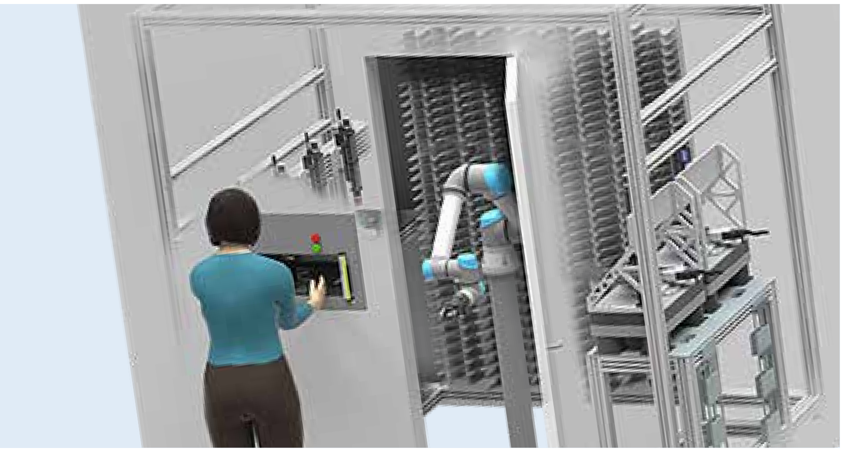
Made at AMOLF or not?
Other engineering colleagues join at an early stage, and the exchange about the technical (im)possibilities begins. The Precision Manufacturing department studies the design and immediately sees a challenge: can they make 250 trays for the petri dishes? Wessel Zwart is involved in producing the trays. “For us, five is already a large batch. The question was whether to outsource production or do it ourselves. But, if we decide to make it ourselves, with what tools and machines? My job is to figure this out. We decided to do it ourselves. The tray consists of seven parts. The trays must all be identical to maximize the accuracy of measurements. Since it is important that the petri dishes always end up in the same position, we attach them to an aluminum tray, which, through three balls, forms a precise support and fits every microscope. The petri dish remains attached to this tray throughout its lifecycle.”

Electronics for control and safety
Although the project is all about collaborating, each person has a clear role to play. “The mailbox is Alexander's,” say the engineers with a laugh. Alexander Evers from Electronics Engineering explains: “The mailbox has a light barrier and indicator →

Henk-Jan Boluijt

Bas Steenbeek

“If someone opens the door to the lab space, the whole process stops. **You don't want to lose 250 samples.**”



Impression of lab with 'Aretha' setup when completed.

Various stages in the manufacturing process of the trays with separate parts.

Tray upside down showing the three balls, forming a precise support.

Tray containing a petri dish.

→ LEDs. A green LED means the researcher can place a petri dish inside. The mailbox hatch remains closed if hands are inside. A sensor detects whether the three balls of Wessel's tray make contact. Only then is the sample correctly positioned, and the robot can pick it up. Each sample gets a unique QR code. Communication with the software about which sample is coming begins at the mailbox. My department is also responsible for all power supplies, cabling, and climate technology." Henk-Jan adds that the entire setup will be reliable: "If someone opens the door to the lab space, the whole process stops. You don't want to lose 250 samples."

Software to instruct Aretha
"We purchase the robot arm externally, Wessel from Precision Manufacturing makes the special robot fingers, and Marco controls the robot," says Henk-Jan. Marco Seynen writes the software for the entire process: controlling the arm, interacting with the mailbox, the microscopes, saving the data, and the data processing. He explains: "I write a program based on the instructions from the researchers. They indicate which dishes they want to measure at regular intervals. The robot works 24/7, moving the petri dishes. When the microscopes are ready, they signal 'I need a new dish.' An ultimate wish is for tasks to run through algorithms, for example, for the video application to film a specific point of interest in the fungus."

Storage and transport: role of ICT
During the conceptual phase, two video microscopes from the original plan were dropped. Bas explains why: "One video microscope generates 20 terabytes of data per day. We can't save 80 terabytes, but 40 is possible." The ICT department was involved in the project early on. Head of ICT Cees van der Ven describes two major challenges: the daily storage of the data and the transport to the supercomputer Snellius at SURF, where the data is processed and archived. Marco adds: "The lifespan of the fungus and all steps of the measurement process are stored in the database. Researchers do not immediately know what they will do with the data. How do you ensure that data from two years ago can be compared with last week's data? You need to tag it well." ICT is developing a web application for 'Aretha'.

"Researchers need to prove later how they obtained their results and that it was done reliably. **Data management is crucial**."

Who gets access to what?
Cees: "Researchers need to prove later how they obtained their results and that it was done reliably. Data management is crucial. An additional complex issue is how we arrange data access. Researchers Tom and Loreto collaborate with other universities and commercial parties. Who gets access to what? For us AMOLF ICT, it's new and exciting to be so closely involved in such a large research project."

Five disciplines collaborating closely
Henk-Jan says the collaboration of all disciplines runs smoothly. There are weekly progress meetings with researcher Loreto. The engineers – "we all love our work" – find continuous brainstorming about improvements inspiring. Bas gives an example: in his design program, everything is perfectly straight, but the table that holds a microscope does not always have an exact 90 degrees angle. Marco discovered that he had to account for this when writing his software. The goal is to have the setup working by the end of the year. As far as the engineers and researchers know, AMOLF will then have a setup with Aretha that is unique in the world and offers many possibilities. Bas: "We are already thinking about new functionalities, such as a module that ensures the robot itself pipettes fluorescent liquid into the samples."•

We love to have fun

Some might say AMOLF is a successful institute because of our groundbreaking impact in the field, our excellent environment for learning and development, or even our cutting-edge equipment. While these are common beliefs outside of AMOLF, we know the true secret to our success: we love to have fun. At AMOLF, we know how to relieve pressure, let off steam, and build strong connections with our colleagues.

For over 25 years, the PV (Staff Association) has been dedicated to keeping the fun alive at AMOLF, providing a much-needed break from work with unforgettable events. We've delved into our old, almost historic photo albums to bring you a selection of the best, weirdest, funniest, and most original drinks ('borrels'), Christmas lunches, outings, and more. We hope you enjoy this delightful glimpse into our past.

A heartfelt thank you to all (former) employees and everyone who has ever joined the PV. You've made AMOLF a vibrant, welcoming, and fun place to be.

Enjoy with us
Borrel playlist

SOLARNL

“Broad collaborations are what we do well, but **we have never done anything on this scale before.”**

Budget: total 898 million euro of which 312 million comes from the National Growth Fund

7 gigawatts
of solar panels every year, enough to be energy neutral by 2050

Partners in the project
9 solar technology companies
6 universities
4 colleges
TNO
AMOLF

“AMOLF has always been strong in setting up broad scientific research collaborations, but the ambitions of the SolarNL project, honored with 312 million euros from the National Growth Fund, are exceptionally high: building a high-tech solar energy sector in the Netherlands”, says project leader Albert Polman.

Text: Bruno van Wayenburg • Photos: Floris Krelage

“Look, this is where the office of the SolarNL program will be located”, says Albert Polman. While walking to the window of his office he points out a building across the car park. “We will also set up a showroom for the solar panels that we are going to develop and provide space for start-ups. On the outside of the building, we will mount solar panels.”

The ambitions are considerable for the SolarNL program. The aim is to help an entire Dutch solar sector get off the ground, from fundamental research to new factories. These factories should produce 7 gigawatts every year, enough for the Netherlands to be energy neutral by 2050. In 2023, the plan received a contribution of 312 million euros from the National Growth Fund.

It is a plan with a long run-up. In the eighties, AMOLF pioneered research into solar cells that were considered expensive and not very efficient. It was swimming against the current: urgency and research funding were lacking.

This changed during the mid-nineties, says Polman. “In 2006 I became director of AMOLF. This is when you get the chance to set up a new department. We realized that sustainable energy was going to be very important.”

Once again, AMOLF put full effort into solar cell research, but Polman felt it was not enough. “In research, it always takes a long time before discoveries end up in applications. Today, you cannot buy panels with AMOLF inventions in them. So over time we thought: can we, together, set up something bigger, including anyone who has anything to do with solar energy, in order to build a new industry?”

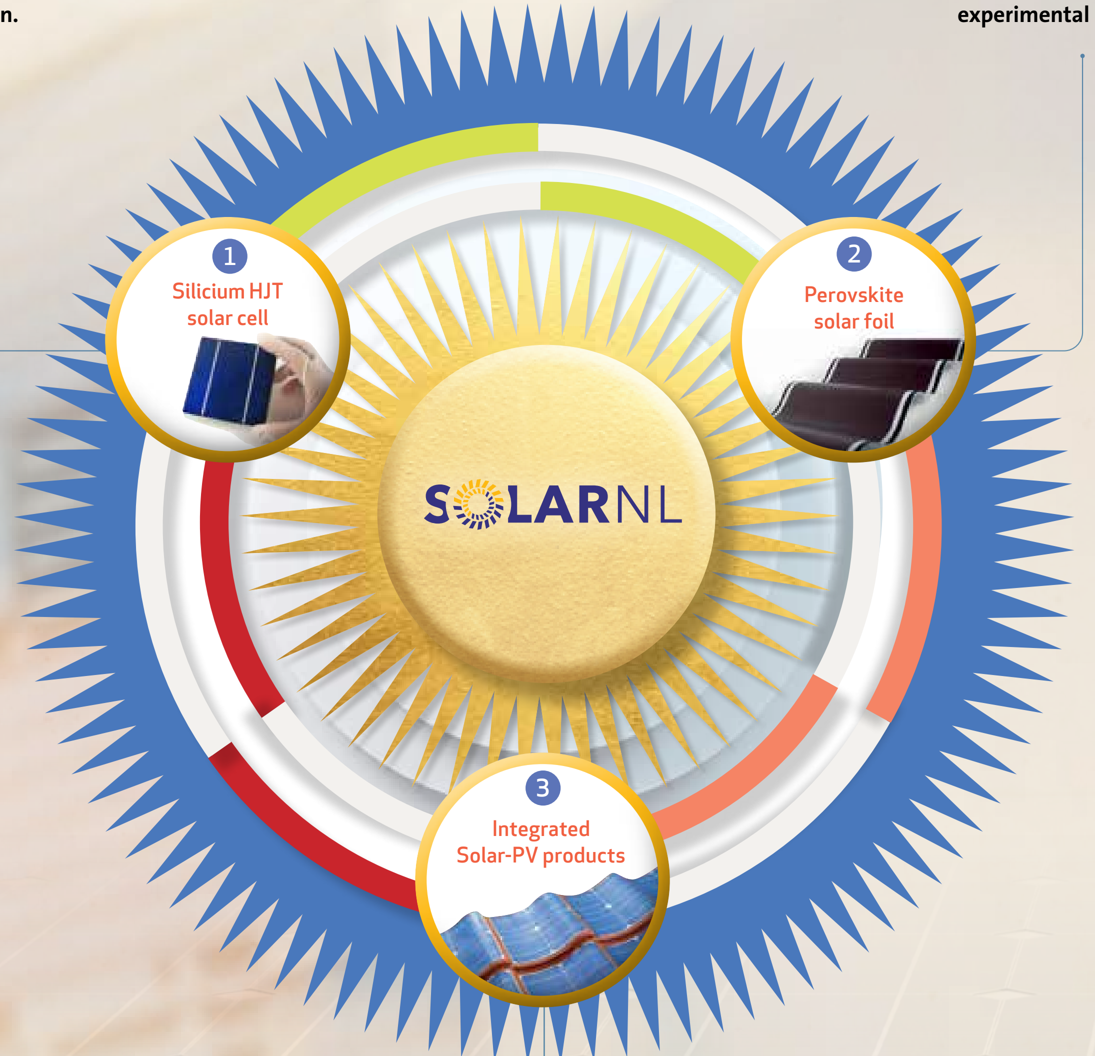
It is unusual for a research institute to try to kickstart an industry, but then again, times have changed. With the Russian attack on Ukraine, ever chilling global relations, and a few hefty disruptions in global supply chains, the realization dawned that you need to have production capacity and in-house knowledge, especially in strategically important areas such as the energy transition.

→

The three goals of SolarNL

Improving high efficiency heterojunction solar cells based on silicon.

Developing futher: lightweight and bendable foils based on perovskites, currently still a largely experimental material.



Developing lightweight solar cells incorporated into building materials.

And we need different kinds of solar panels here. In the Netherlands, where space is scarce, we would need to fill an area of a thousand square kilometers with solar panels to become energy-neutral. But, we could increase the efficiency of the panels." Only half of all Dutch roofs can support the weight of the heavy standard issue solar panels. "This is why we look at lightweight solar panels, and solar cells encased in building materials."

The SolarNL program aims at three goals. One: improving high efficiency heterojunction solar cells based on silicon. Two: the further development of lightweight and bendable foils based on perovskites, currently still a largely experimental material. And three: the development of lightweight solar cells incorporated into building materials.

Partners in the project are nine solar technology companies, six universities, AMOLF, TNO and four colleges. Out of the total 898 million euro budget, 586 million comes from private funding. The money will go towards setting up production facilities, but there is also a focus on research and setting up education programs for technicians. A key requirement is circular production, says Polman. "To recycle solar panels, you have to be able to separate the layers after its useful life. This is something you have to take into account during production."

Large collaborative projects are no stranger to AMOLF. In the past, the institute coordinated a project on nanophotonics together with Philips. And, as another example AMOLF developed mass spectrometry, first for isotope separation, says Polman. "That research eventually found its way to all kinds of applications too, including medicine."

Nevertheless, Polman is willing to acknowledge that the ambition is exceptionally high this time. "Broad collaborations are what we do well, but we have never done anything on this scale before."

Incidentally, AMOLF itself will not build factories, or sell solar cells. "We are the coordinators, the program office is here, and we do research. As a scientific institute, we are well equipped for that. We are good at establishing contacts and making connections, and at setting up and writing down a coherent plan. AMOLF is at the center of the hub here."•

"In the Netherlands, where space is scarce, we would need to fill an area of a thousand square kilometres with solar panels to become energy-neutral. **Or we could increase the efficiency of the panels.**"

SUNLIGHT IS MAGIC

overwhelmingly abundant
yet so hard to capture
and let alone use
so we cannot but choose

to explore and design
to convert and refine
to try and control
how energy flows

to uncover the magic
of charge, matter, light
and how they intertwine
at the photonic level

we cannot but take
one step at the time
towards a world
truly powered by light

Bauke Vermaas
Science writer and Zwolle city poet

Forty years of solar cell research

Visionary scientists driving solar cells forward

1984 — 2024

For forty years, AMOLF has been engaged in fundamental solar cell research, leading to many notable successes. Three AMOLF physicists initially gave solar cell research the crucial push at the right moment, proving to be visionary in their approach. Frans Saris (born in 1942), Wim Sinke (born in 1955), and Albert Polman (born in 1961), colleagues from successive generations, still stay in touch. “We talk about the development of technology and its consequences for the world. We maintain a wonderful mentor-student relationship,” Albert shares.

Text: Anita van Stel

Early 1980s

Everything started in the early 1980s. At that time, many people said that solar cell research would never amount to anything. Critics argued that efficiency was only 8%, the technology was extremely expensive, and scaling up to larger areas was almost impossible. But, at the time Frans already argued that solar energy was a key alternative to fossil fuels and he brought the research to AMOLF. He began with a few PhD students, including Wim Sinke and Dick Hoonhout, who were among the first to conduct experiments. In 1984, Albert joined them as a young graduate student.

Cheaper production

In his office at AMOLF, Albert shows two illustrations from his master’s thesis: a comparison of the dirty emissions of a diesel generator with those of a clean solar power plant. He laughs at the images: “We were already very politically engaged in 1984.” He explains that in the early phase, the research mainly focused on making solar cells more efficient cheaper to produce. “We had no idea how to go about that.” In 1986, Frans became the director of AMOLF. Wim Sinke completed his PhD, became a group leader at AMOLF after a postdoc in Japan, and expanded his group with more PhD students, including Albert.

To ECN in Petten

Frans became the director of AMOLF in 1986. By then, Wim’s group was making solar cells on a larger scale at AMOLF and also began collaborating with companies. Albert recounts that Wim’s researchers, at one point, were pushing carts full of solar cells made in HolecSol’s factory through the AMOLF building to test them here. Albert says, “Frans concluded that the work had transcended fundamental research.” Wim seized the opportunity to move his group to ECN to further develop and scale up the technology. The entire research group, along with all the equipment, relocated to ECN in Petten. Wim established the solar energy department there, which now employs more than 60 people.

Ten years of inactivity

After a postdoc at AT&T, Albert was hired as a group leader at AMOLF: “I moved into Wim’s empty lab and focused on photonics. It was a tough time for funding fundamental solar cell research. There was a lot of skepticism, and the climate problem was not yet widely recognized. Meanwhile, Wim was very successful at ECN. Frans also moved to ECN: his term as director of AMOLF ended in 1996, and he then became director of ECN and thus Wim’s boss. In that role, he led the sustainability efforts at ECN and strengthened collaboration with AMOLF.”

Late 1990s

Albert: “In the late 1990s, a revolution took place in solar cell research. Much credit goes to a researcher in Australia, Martin Green, who reasoned that solar cells should be made in cleanrooms like computer chips because cleaner manufacturing yields higher efficiency. He built a cleanroom in his own lab and raised the efficiency to above 20%,which opened up more research opportunities, including for us.”

Frans Saris

Wim Sinke

Albert Polman

Photos: Archive AMOLF, Anjo Brombacher, Floris Krelage

A new theme

The turning point came around 2005, as solar cell production became increasingly cheaper, with the expectation that costs would continue to fall. This renewed AMOLF’s interest in solar cell research. Albert: “It seems unimaginable now, but fifteen years ago, hardly anyone knew what a solar panel was. As the director of AMOLF, I was able to introduce a new theme in 2010. In solar cell research, ‘light’ was still a forgotten phenomenon because almost everyone was focused on developing better materials. AMOLF held a unique global position with its knowledge of nanophotonics, which we then applied to solar cell research: by cleverly capturing light, we achieved a significant efficiency improvement. We chose to combine photovoltaic materials, nanophotonics, and spectroscopy, and once again proved to be visionary. We started a Center for Light Management in Photovoltaic Materials (LMPV) and built an international reputation. The starting point was a visionary paper that has now been cited more than 6000 times.”•

> “Fifteen years ago, hardly anyone knew what a solar panel was.”

2024 New Solar Energy team

In the new photovoltaics theme, AMOLF was able to attract new group leaders with original ideas and different expertise: Erik Garnett, Bruno Ehrler, Esther Alarcón Lladó, and Wiebke Albrecht. Together, they form a new, strong solar energy team. Each person is an expert in a particular field, also beyond solar cell research, and the strength lies in the sum of the parts. This year, they won the Team Science Award from NWO. These group leaders, in turn, are the mentors for the new generation, a large group of young people, very diverse, with as many women as men.

Photo: Liesbeth Dingemans

The Solar Energy team: Bruno Ehrler, Albert Polman, Esther Alarcón Lladó, Erik Garnett and Wiebke Albrecht.

Isabelle Palstra, new NanoLab manager

AMOLF upgrades state-of-the-art NanoLab

Smooth transition

In the hallway at AMOLF, equipment sits temporarily stored, packed in plastic. Behind it, construction workers are finishing the ceilings inside the cleanroom. It is early August, and the new NanoLab, with plenty of brand-new equipment, is scheduled to be ready for use by mid-September. When that time comes, Mr. NanoLab, Hans Zeijlemaker (almost 67), will retire, and Isabelle Palstra (32) will succeed him. "I think she will do well", Hans compliments his successor.

Text: Anita van Stel • Photos: Igor Hoogsteder

From Vacuum Technology Lab to NanoLab
When Hans leaves AMOLF in October, he will have spent 44 years at the institute. "I haven't been grumpy here a single day," he says. Hans was hired as a technician by Jan Verhoeven and Gerrit Frijlink. "It was remarkable, because I came with many stripes from military service, and Frijlink was a outspoken pacifist." In 1980, AMOLF was primarily focused on surface physics. AMOLF's Vacuum Technology Lab was the specialist in vacuum technology. Hans: "Vacuum technology was still a research field back then. We had the highest quality vacuum in the Netherlands." The vacuum lab was first split into a thin film lab and a cleanroom; in the current AMOLF building, everything merged into NanoLab, with Hans as the manager.

Making samples yourself
In this NanoLab, many PhD students have been trained in making samples. Hans: "That's part of the AMOLF approach, because every PhD student learns firsthand what is and isn't possible. Since there is a high turnover of PhD students, the NanoLab constantly provides a lot of training on how to operate all the equipment," Hans explains. Isabelle was one of those PhD students: she completed her PhD in the Resonant Nanophotonics group of Femius Koenderink. Isabelle: "I enjoyed the fabrication of the samples, but I also wanted to know everything about the underlying process from the staff members."

Subsidy for new equipment
While NanoLab is an AMOLF facility, it is also connected to the national collaboration NanoLabNL, along with NanoLabs in Groningen, Twente, Eindhoven, and Delft. Through the National Growth Fund program Quantum Delta NL, the NanoLabNL foundation received funding for infrastructure. For AMOLF, this meant a contribution of 12 million euros. Hans is pleased with the subsidy, which finally allowed for the replacement of old equipment. He explains that there is always a shortage of space at AMOLF and that he had to place their old TEM (transmission electron microscope), a gift from ASML, in a too-small lab space out of necessity.

More space
AMOLF wanted to improve the quality of the NanoLab on several fronts. The lab space needed to be larger, to accommodate more new equipment, thereby creating more possibilities. The lab's requirements were tightened: the space had to be used more effectively, be better shielded from external disturbances, and the cleanroom had to be cleaner.

Starting over
Preparations for the renovation began in early 2022. Hans says, it quickly became overwhelming: "It became increasingly complex, involving more and more disciplines. We could figure out the specs for equipment ourselves, but things like air treatment are too far from my expertise. We were done with compounding expansions, and there was only one solution left: tear everything down and start all over. For an expansion of this scale, we needed external support."

Hans retires
AMOLF decided to hire a project manager for the renovation and equipment purchase. Femius tipped Isabelle off about the vacancy. Isabelle:"It sounded like an interesting opportunity for me. I always enjoyed working at AMOLF; I found it a pleasant workplace, and this was a great way to gain both management and hands-on technical experience. I started as a project manager in November 2022. When Hans' retirement came around, I decided to apply for his position. In this position, I can work in an academic setting without the hectic lifestyle of academic work. It feels surreal; this isn't the career path I would have predicted a few years ago, but I feel very fortunate to have this job."

Smooth transition
Hans says that with Isabelle, NanoLab is getting someone at the helm with a different type of much-needed knowledge. Hans: "I'm not an academic. This lab needs a different type of knowledge." Isabelle adds: "If you've completed a PhD, you can understand PhD students and the academic process better. I think that will help me." Both agree that the transition has gone smoothly. Isabelle relied on the existing expertise in Hans' group when drafting European tenders to purchase equipment. Hans: "I could gradually take the back seat." Isabelle: "After the renovations, I'll slowly acquire all the other knowledge I'll need, with the help of the technical staff.

Translating signals from science into opportunities
What will Isabelle do differently than Hans? Hans says everything will be different: "She'll have a state-of-the-art new lab, and that's fantastic." Isabelle mentions that she wants to implement stricter rules for wearing protective clothing in the lab: "Dust particles can negatively affect the work, and nobody wants that." She also plans to get more out of the collaboration with NanoLabNL: "Our technician Laura Juškėnaitė is currently doing an internship at NanoLab in Delft to study etching processes with the technicians there. It's my job to translate signals from AMOLF scientists into potentially interesting opportunities to collaborate with other NanoLabs. We can achieve more in collaboration with external parties."

Notable projects
Hans mentions several notable projects NanoLab has developed with external partners like DELMIC, Thermo Fisher, ASI, Edax, and recently JEOL, for our new TEM. Isabelle hopes to do more such projects in the future. Isabelle: "We're expanding the team so that the technicians have time not only for maintenance and teaching but also to improve the equipment." Hans emphasizes to Isabelle that this is important: "You have to keep people motivated. Take Igor Hoogsteder, for example, who is an expert in coupling light into the TEM and he can pass that knowledge on to the rest." Isabelle nods and smiles. "We play an essential role in many scientific processes at AMOLF. I'm happy to be here supporting and advancing research."•

"We play an essential role in many scientific processes at AMOLF. **Supporting and advancing research is something I find wonderful.**"

Hans Zeijlemaker, former NanoLab manager

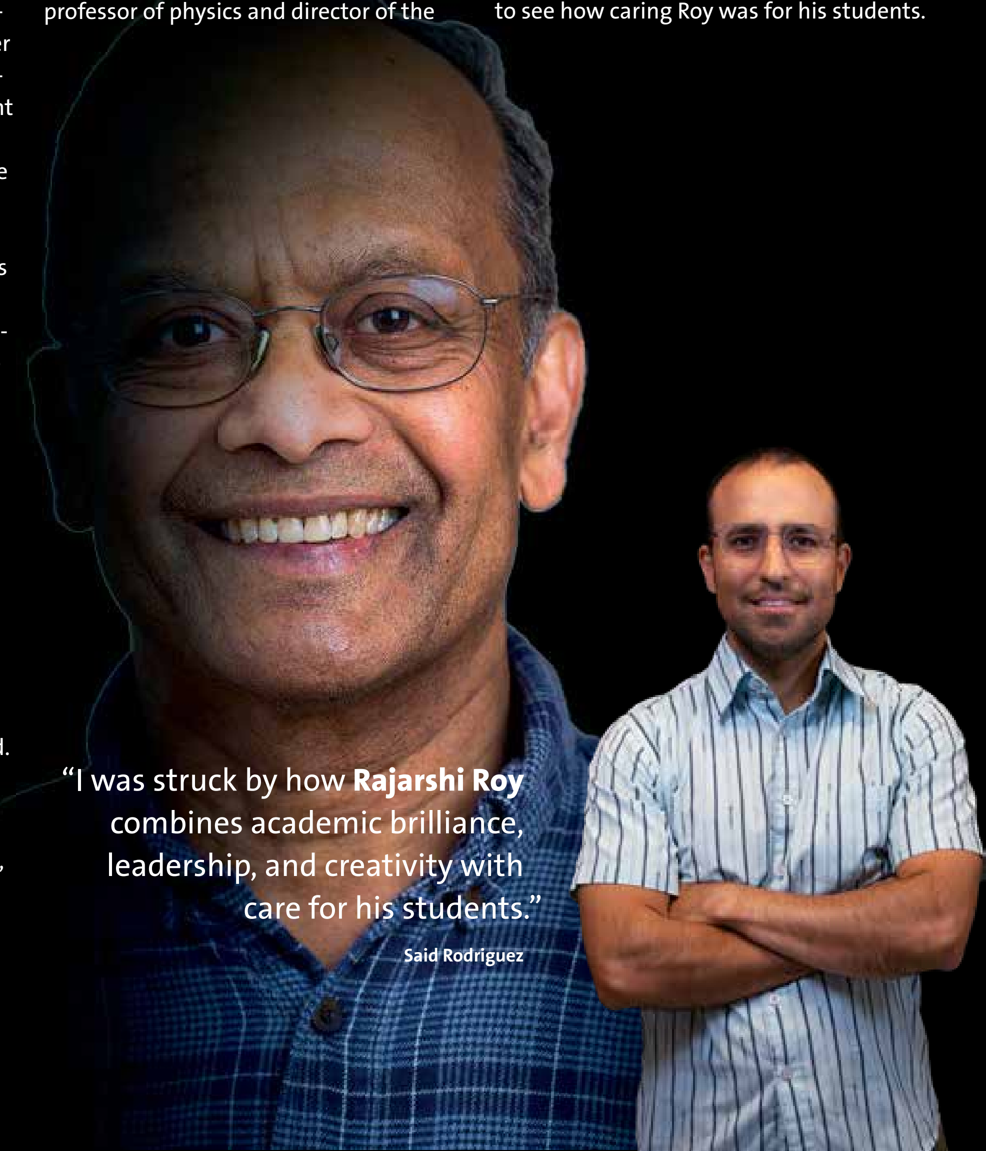
Empowering **diversity**

AMOLF is actively stimulating diversity, and offering a variety of role models to students and junior researchers is one of its priorities. Two group leaders talk about the role models in their careers.

Text: Mariette Huisjes • Photos: Floris Krelage

"A role model is someone you admire, but not from a distance. You must recognize something in the person", says Esther Alarcón LLadó, leader of the 3D Photovoltaics group at AMOLF and professor of nanoelectrochemistry at the University of Amsterdam. Maybe the same kind of upbringing, maybe gender, maybe character or personal style. The combination of admiration and recognition makes you want to follow in the role model's footsteps. Of course you cannot become exactly like them, but you want to emulate some of the things the role model does well.
For Esther, Anna Fontcuberta i Morral has been a role model. She is a physicist and material scientist at the Ecole Polytechnique Federale de Lausanne (and its future president as of 2025). She has a Spanish background like Esther and is equally a woman in a male-dominated work field. After hearing her speak at a conference, a spark flew and Esther applied to be a postdoc in the Fontcuberta lab, in which she succeeded. "I admire how she tackles challenges", says Esther. "With an attitude that is both positive and pragmatic. And she always makes such a fresh impression; whenever you leave a conversation with her, you feel energized. She can be blunt, and tell the truth if it is important, but always in a caring way. After working with her for a few years, I realized how important role models are."

Generous style
Said Rahimzadeh-Kalaleh Rodriguez is leader of the Interacting Photons group at AMOLF. After some reflection he also identifies a role model who has been inspiring him for years. It is Rajarshi Roy, professor of physics and director of the Institute for Physical Science and Technology at the University of Maryland. Like Said himself, who grew up in Mexico, the Indian-born Roy belongs to an ethnic minority in a work field that has long been dominated by Europeans and North-Americans. "I have not actually worked with him, but I have interacted with him on a few occasions, and I was struck by how he combines academic brilliance, leadership and creativity with care for his students. In the academic rat race, being self-centred mostly pays off and those who act in a self-centred way then are presented to us as role-models. Against that backdrop, I found it inspiring to see how caring Roy was for his students.



"I was struck by how **Rajarshi Roy** combines academic brilliance, leadership, and creativity with care for his students."

Said Rodriguez

He is also a strong champion for giving chances to minorities and supports this through his actions. For instance, Roy regularly gave workshops for students with challenging backgrounds from Africa and other places with little budget for higher education. He did experiments with them and taught them physics; I admire this generous style."

AMOLF and diversity
AMOLF has been actively working on diversity since 2018. Some goals of the current plan are to safeguard an inclusive work culture and to improve the recruitment and career progression of underrepresented groups. There is an active Diversity, Equity, Inclusion (DEI) team, chaired by Esther. It initiates actions, evaluates progress and organizes all kinds of activities, such as the biannual Diversity Day. "It is hard to put a finger on it, but my intuition is that since I entered AMOLF in 2017, it has become more diverse", says Said. "To me, it is important that diversity should be sought not only in gender, but in ways of thinking. Such different perspectives may correlate with gender, but also with cultural background or neurodiversity. Academia needs people who think outside the box, who are not focussed so much on fixed protocols but more on the end results."
Esther is also satisfied with how things are going at AMOLF, especially with how young PhDs from minority groups seem more empowered nowadays, how they have found their voice and want to be part of the DEI team for instance. However, she warns that some privileged people mistakenly seem to think the problem has now been solved. In reality, the old biases are not uprooted yet, and still some talented people get fewer opportunities than others. "We need to keep awareness alive."

"**Anna Fontcuberta i Morral** always makes such a fresh impression; whenever you leave a conversation with her, you feel energized."

Esther Alarcón LLadó

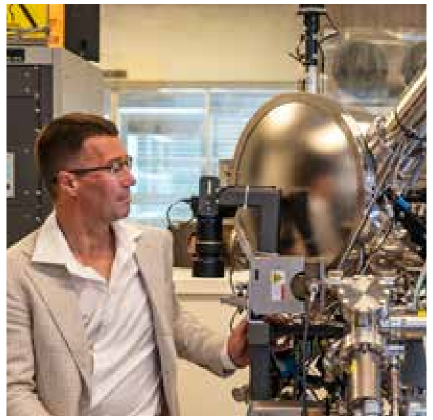
Choice in role models
Of course, as successful scientists and representatives of minorities, Esther and Said can also be role models themselves. Are they aware of that?
"I am aware but I also try to ignore it a bit, because I feel the pressure", says Esther. "At the same time, I do realize the importance of someone with my background and gender managing to get a position at a prestigious institute such as AMOLF. After all, I had to move literally all around the globe to get where I am now; it's good to show that this pays off in the end. I would have liked to have such a role model when I was a student." Said also does not often stop to think about himself as a role model. "Unfortunately I have not gotten to the point yet where I can make the same investments in minority groups that Rajarshi Roy did. However, I am sometimes told that people find my provocative way of thinking inspiring. I like to challenge standard ways of thinking. Maybe that has something to do with my cultural background; we Mexicans are a bit more spicy than most Europeans." The crux of the matter is that AMOLF strives to offer a diversity of role models, says Esther. Not only within the institute, but also when inviting guest speakers or visiting scholars. "There is not one role model that works for all. You need a variety of role models, so that young people can choose who they find inspiring. Maybe they have not one but several role models, from whose examples they construct their own style. Offering this option is certainly one of the goals we are working towards with our diversity policy." •

Fundamental physics finding its way to **the hospital**

Many years ago, Ron Heeren established fundamental research in mass spectrometry and imaging of molecules at AMOLF. When fundamental physics gradually changed to applied medical and biological research, he moved his group to Maastricht University. His renowned M4I institute research enables the visualization of molecules on and in cells to help clinicians improve their therapies.

Text: Bastienne Wentzel • Photos: Harry Heuts

After a PhD in technical physics, Ron started his career as a postdoc at AMOLF in 1993. Shortly after, he established his own research group on macromolecular ion physics. Ron has good memories of those times: “I recall regularly having coffee with Jaap Kistemaker, founder of the FOM laboratory of mass spectrography and pioneer in the separation of isotopes. If I shared the latest developments in mass spectrometry with him, he would say: ‘No, that's impossible!’ But then I showed him the results and he would say: ‘That's impressive, congratulations!’ I thought that was fantastic!”



Developing new instruments

Mass spectrometry is a technique to identify molecules by analyzing their molecular weight. At the time when Ron started, it was impossible to study intact macromolecular ions. It was necessary to create fragments of molecules prior to their analysis and then put the pieces of the puzzle together to obtain structural information of larger molecules.
Ron recalls: “At a certain point a new Nobel-prize winning technique became available: electrospray ionization, with which we could ionize intact very large molecules, such as proteins and DNA. But the mass spectrometers in those days were not good enough to analyze these ions. Our task was therefore to build a new instrument that would enable intact macromolecular analysis.” With the new instrument, Ron’s group was successful in analyzing the proteins. In the following years, they built many new instruments, and the group's focus shifted to biomolecular imaging mass spectrometry. The colorful images that these instruments produce of samples like tissue or cells, provide information on the spatial organization of the molecules on the sample surface. “We developed fantastic instruments, we improved the resolution and increased the speed of the measurements. Many of the techniques we developed, are now implemented in commercial instruments. Our group grew and our focus shifted from fundamental to applied biomedical research. My wish became to implement our knowledge in a clinical environment, which was difficult at AMOLF.”

Move to a clinical environment

“What I appreciate in AMOLF is its role as an incubator,” says Ron. “Fundamental research and out-of-the-box ideas are nurtured and given space to grow. If they are successful and would benefit from further development outside the institute, this is encouraged.”

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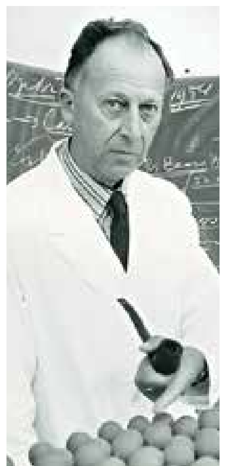
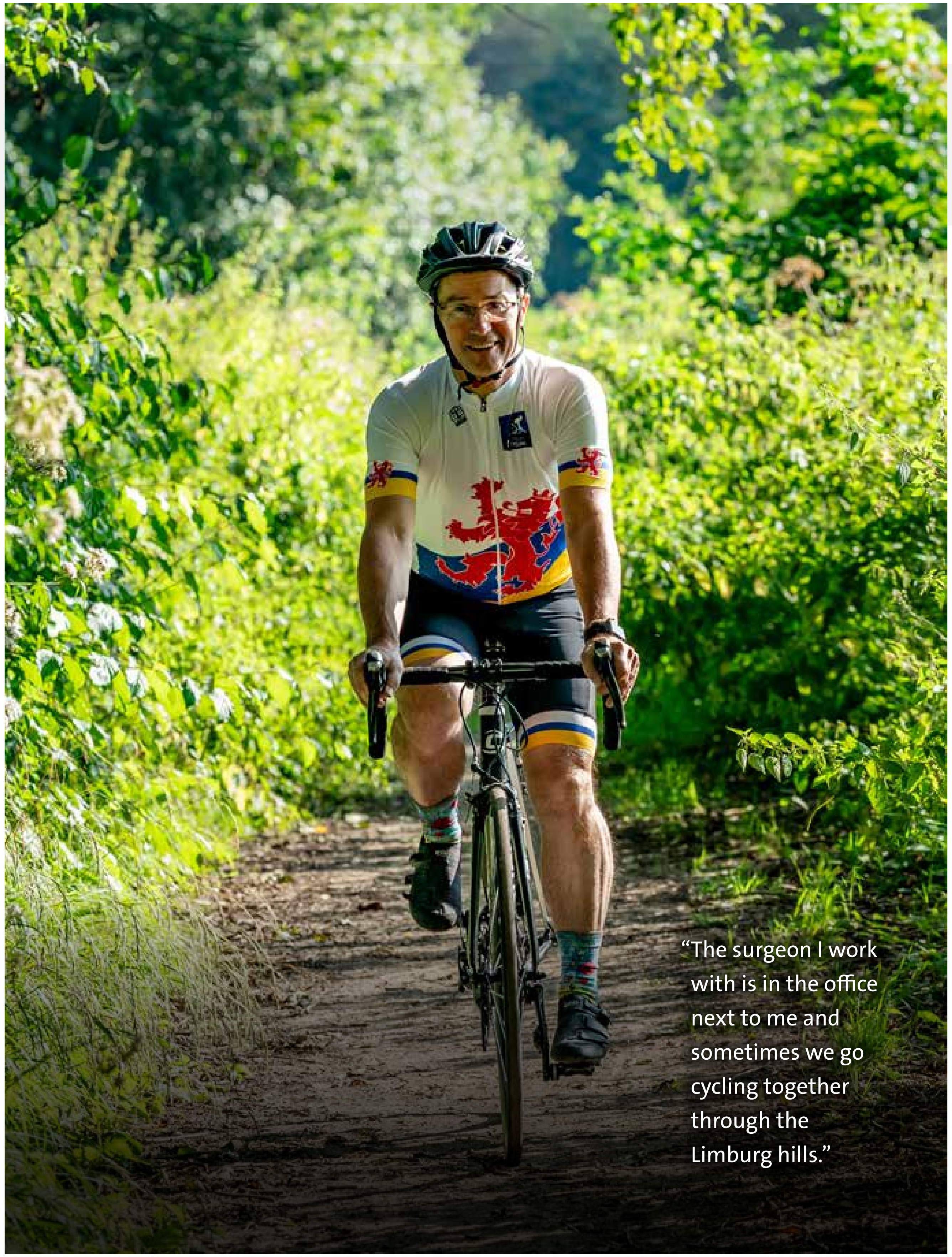
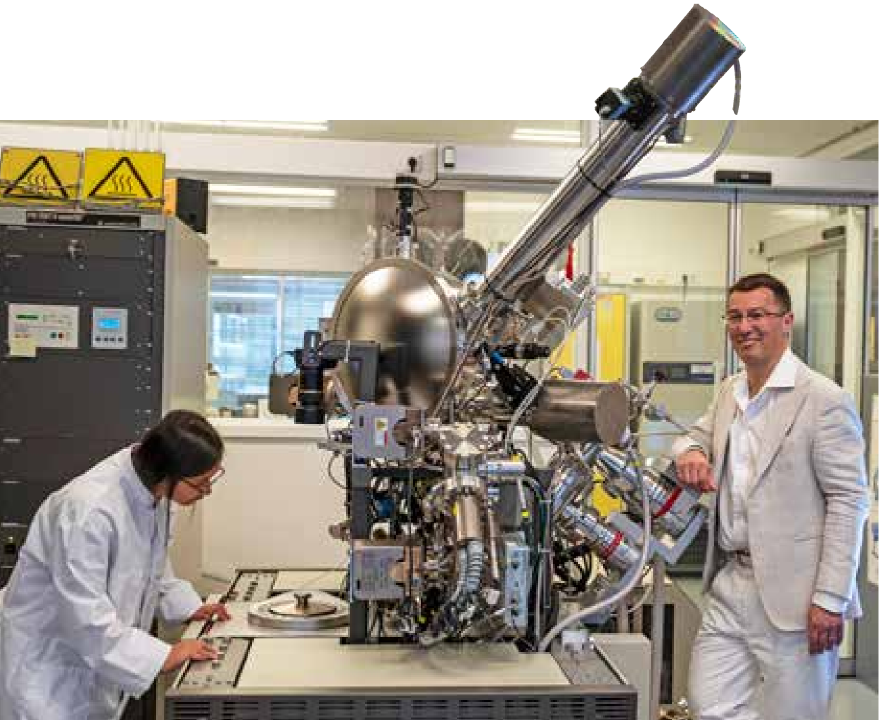


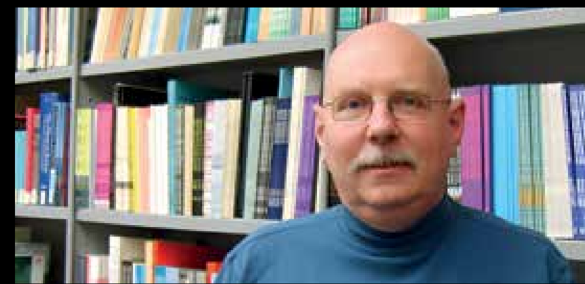
Photo: archive AMOLF

“Kistemaker would say: No, that's impossible! But then I showed him the results and he would say: **That's impressive, congratulations!**”



“The surgeon I work with is in the office next to me and sometimes we go cycling together through the Limburg hills.”





“**Jaap Boon** was the prototype ‘homo universalis’. He taught me to think across the boundaries of disciplines and to develop a biological and application-oriented view.”

We did a successful analysis of Rembrandt’s ‘Anatomy Lesson of Dr. Nicolaes Tulp’.

With special thanks to museum Mauritshuis

→ “So it happened that I was asked to think about developing my ideas elsewhere around 2014. I wasn't sure, but what really convinced me to move, was a meeting with a surgeon. He asked me to help analyze isotopes relevant for a metabolic disease. We solved his issue within five minutes and that helped their patient research. Then, I realized that by working in a clinical environment I could really make a difference. The young University of Maastricht was very accommodating and offered me a position. That was the start of the M4I institute, where I am still the director.” The M4I (Maastricht MultiModal Molecular Imaging Institute) is one of the largest molecular imaging centers in Europe. The group now has 80 academic staff members and 45 high-end mass spectrometric instruments. Its focus is on a better integration of fundamental and clinical research. “In our office, the surgeon, pathologist, mathematician and MS specialist are neighbors. They casually learn from each other, which creates a new research dynamic that I really value.”

“The results allow the pathologist to identify the cell type, see if it is active or distinguish between a malignant or benign tumor.”

High resolution images

“A particularly important development for the institute is the mass microscope”, says Ron. “The idea for this technique was funded at around the year 2000. But, at the time the technical challenges were too big: detectors and software were not fast enough for the huge amount of data it produced. This could be up to a terabyte per minute.” Just two years ago, using a modified version of the first instrument, the mass microscope started to flourish. Conventional imaging mass spectrometers produce images by scanning dot after dot of a sample, 40 to 1000 dots per second. The smaller the dots, the higher the resolution of the image but the longer the measurement takes. A pathologist needs an analysis of an entire biopsy, for example of a tumor. Scanning a sample of this size would have taken a year with the old equipment.

Ron: “Using the new instrument, we can scan one million pixels per second and obtain the result in minutes. The results allow the pathologist to identify the cell type, see if it is active or distinguish between a malignant or benign tumor. That information helps clinician to tailor a better treatment for the patient.” The next step is the ability to image a living, dynamic environment. At present, the samples are frozen and static. “Imaging dynamic samples is now only possible by labeling molecules for example with a fluorescent probe and an optical microscope. We are working on a mass spectrometry imaging technique for dynamic samples that do not require labeling.”

Aging paintings

Recently, Ron re-entered an entirely different field of application of imaging mass spectrometry: studying the molecular composition of art. At the start of his AMOLF-career, he was involved in the research program MolArt, which studied the molecular aspects of art aging – using mass spectrometry – together with Jaap Boon. “We did a successful analysis of Rembrandt’s ‘Anatomy Lesson of Dr. Nicolaes Tulp’, which I still use as an example in lectures. Jaap Boon taught me to think across the boundaries of disciplines and to develop a biological and application-oriented view. He was the prototype ‘homo universalis’, I owe to him my passion for interdisciplinary research.” Jaap Boon recently passed away. Ron: “Meeting old colleagues at the ceremony was the start of several new projects in the field of molecular aspects of art. I think Jaap would have liked that.” Ron has always valued the sense of togetherness within AMOLF. “We were pioneers and the institute always stimulated out-of-the-box thinking. This freedom and the dynamic and interdisciplinary ecosystem is present in Maastricht as well. That is why I feel so much at home there. The surgeon I work with is in the office next to me, and sometimes we go cycling together through the Limburg hills. Feeling at home at work is a crucial element for a successful scientific career.”•

“**We were pioneers** and AMOLF always stimulated out-of-the-box thinking.”

UNDERNEATH

while we gather, transport and
process ever smaller bits of data

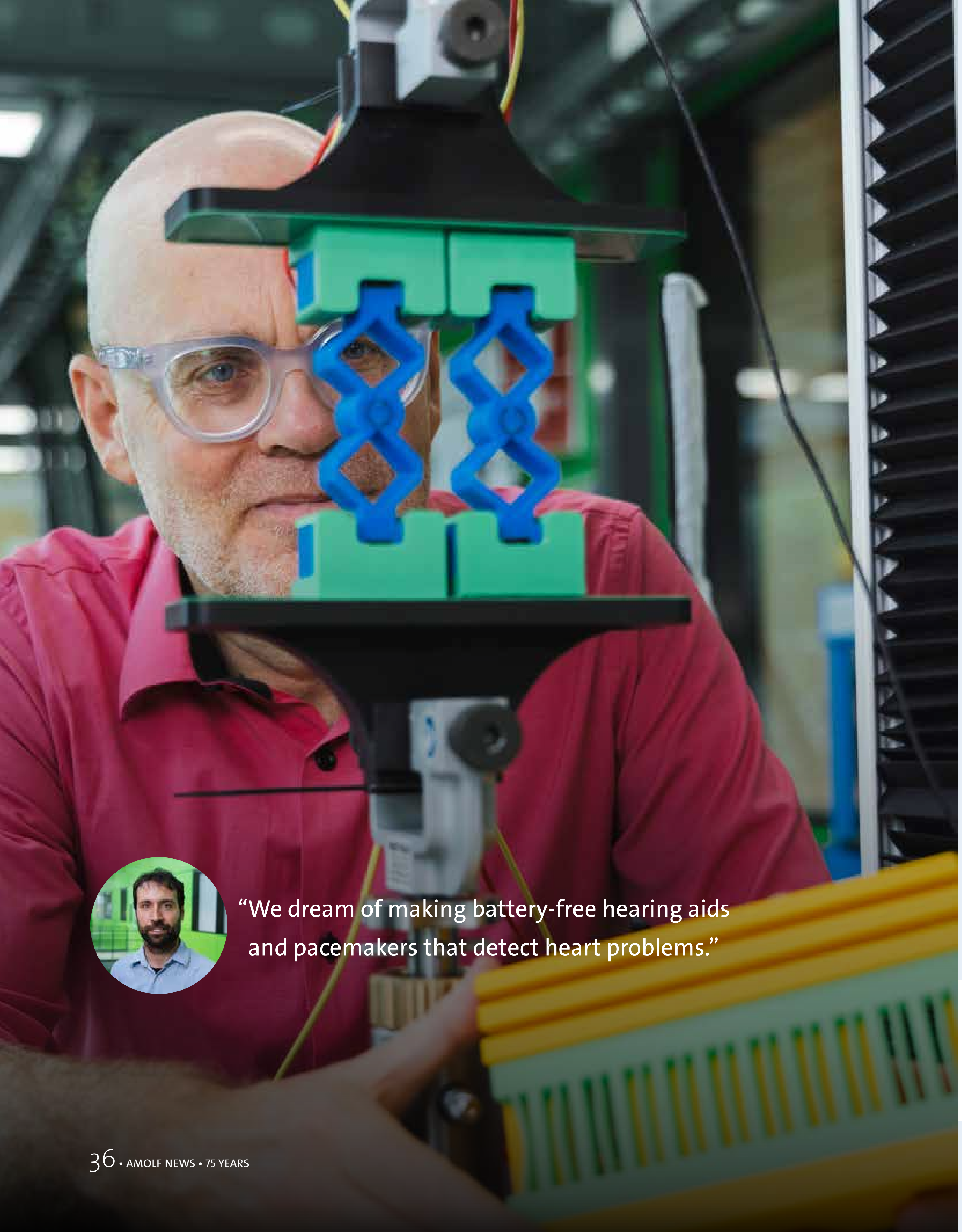
we are finding ways to follow
information throughout matter
however crumpled or complex

we are creating tiny strings
for light and sound to sing together
and materials that can remember

we are approaching and stretching
the limits of sensing and inventing
a language to describe

the beauty of information that hides
underneath the noise of life

Bauke Vermaas
Science writer and Zwolle city poet



“We dream of making battery-free hearing aids and pacemakers that detect heart problems.”

Creating materials that **understand** us

Martin van Hecke, Marc Serra-Garcia and colleagues work on the AMOLF theme Information in Matter, designing materials which can process information without electronics and with little to no power supply. “Future computing will not be limited to energy-guzzling electronics.”

Text: Dorine Schenk • Photos: Floris Krelage

We live in the era of information. From smartphones to traffic lights, everything contains information processing electronics. “We have gotten used to reaching for computers whenever we need to process information,” says Martin from AMOLF and Leiden University. “Computers are useful. But, they have limitations, like their unsustainable energy demand.” For example, the energy consumption for Artificial Intelligence (AI) doubles every three to four months.

In mobile devices, power is provided by heavy and polluting batteries – that eventually run out and need replacing. That creates a huge waste problem. An EU study forecasts that in 2025, 78 million batteries will end up in the rubbish daily. Other limitations of electronics are conversion and speed. Cameras and microphones first convert images and sound to electronic signals before computers process and analyze it, which is inefficient and can be too slow.

Several research groups at AMOLF work on alternative, efficient ways of information processing without electronics, using cleverly designed materials. These materials range from rubber structures that can count, to so-called analog metasurfaces that process optical or acoustic signals without converting them to electronic signals.

These alternatives will not replace our current computers. Martin: “I think that computers will move towards heterogeneous computing, where different tasks use different computing strategies.” AMOLF’s group leader Marc adds: “I think we might move to a world were self-driving cars process images with optical metasurfaces and sound mechanically, because you save energy by using the natural physics of the signal.”

Metamaterials

“This research at AMOLF dates back to about ten years ago,” says Martin. “Around that time, we started to understand complex materials better and we began designing metamaterials.” Metamaterials and metasurfaces are artificially engineered to have properties that are rarely observed in naturally occurring materials, like a cube where a smiley pops out when compressed. And passive metasurfaces with minuscule structures that direct light around sharp corners without losses.

Mechanical metamaterials

Marc’s research group investigates acoustic information processing by structured mechanical metamaterials. They work on networks, consisting of interconnected resonators, that can sense and process vibration signals without electronics, by utilizing energy from the signal. Those vibrations can be a heartbeat or sound. “We design these networks with theoretical models and test them in computer simulations”, says Marc. “Parallel to that, we work on experimental prototypes.” →

About three years ago AMOLF introduced the research theme Information in Matter. Here research groups investigate how living systems, like cells or bacteria, process information with just a few molecules, how nanostructed metasurfaces can direct light such that the surface processes an input image, or how metamaterials can be designed to process information. Martin: “We went from researching metamaterials to using them as a tool for information processing.”

→ The flagship project of Marc's research group is passive speech recognition. "We are trying to make a passive material that understands you when you talk to it," he explains. In 2021 the group developed a sensor that can distinguish between the spoken words 'three' and 'four' (see box: 'Passive speech recognition'). "We dream of making battery-free hearing aids."

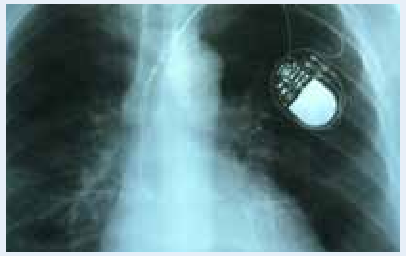
Martin's research group focuses on computing with 'material bits'. "Take for example crumpled paper, which can be described as a collection of bits, where the hills are ones and the valleys are zeroes", he explains. "By compressing the crumple, we change these bits: we interpret that as computing of the crumple." Martin investigates the underlying principles behind such intrinsic properties of materials for use in information processing. "Earlier work on self-folding metamaterial, which folds itself up in several steps, gave me the idea of metamaterials that count," says Martin. After years of research and prototyping, he and his students developed a rubber structure that counts how often it is compressed (see box: 'Computing with rubber').

Applications

"The research field of information processing in matter is growing," says Martin. "But there is still a lot of work that needs to be done. The current state of the art is mostly demonstrating new principles."
However, as always, this fundamental research is also already leading to unexpected applications. Martin is working with colleagues in Delft to translate his metamaterials to a battery-less sensor that counts how often a structure – like a wind turbine – endured stress. This can tell you when maintenance is needed. And Marc is exploring with colleagues from Bologna how to use the acoustic metamaterial for leak detection in water pipes. "These leaks produce a specific, recognizable noise. We are researching whether we can detect these leaks with mechanical, battery-less devices."
"As scientists, we like to focus on ambitious projects that are a bit science fiction, like passive speech recognition," says Marc. "But, I think the main societal impact will come from somewhere else, like battery-free leakage detectors or pacemakers that detect heart problems. I think these devices are accessible within a few years and can be extremely useful."
"However, we are not only driven by these practical applications," says Martin: "AMOLF is a research institute that focuses on long-term fundamental research. That means that we are laying the groundwork for what computer technology may look like 20 years from now."•


Maintenance alert for wind turbines.


Hearing aids without batteries.


Pacemakers that detect heart problems.


Leak detection in water pipes.

Computing with **rubber**

A research team led by Martin, has demonstrated how a smart metamaterial can carry out simple computational tasks, like counting. This metamaterial consists of connected rubber beams that act as mechanical bits – they form zeroes and ones depending on whether they bend left or right. The researchers first designed a two-bit binary counter. If you pull on the structure, the beams pop back and forth in sequence, making the material count from '00' to '11' in binary (from zero to three); the material counts back to '00' by pushing. Three-bit metamaterials can achieve more complex computing, equivalent to what computer scientists call 'finite state machines' – devices that control everyday processes, such as turnstiles, combination locks or vending machines. For example, a turnstile unlocks in response to the insertion of tickets but locks again after a customer has entered and rotated the wheel: it thus combines memory with simple computing. The three-bit metamaterial can precisely perform this computation.

Passive **speech recognition**

Marc's research group and researchers from ETH Zurich have developed a prototype sensor that can distinguish between the spoken words 'three' and four.' The prototype consists of a network of thin plates that, like a tuning fork, resonate at certain sound frequencies. Plates with different resonant frequencies are connected by bars, causing the whole system to resonate at certain patterns or frequencies, like those produced by words. It can distinguish 'three' and 'four,' because the word 'four' resonates more with the network compared to 'three.' The prototype has some limitations. For example, the processing is not in real time. The words must be played almost ten times faster because the device lacks the right dimensions to process speech frequencies. "We are currently working on miniaturizing the design to a chip of a few millimeters, that can process speech frequencies and will fit in a cell phone," says Marc. "And we are optimizing it to be able to distinguish between up to twelve words, like 'on,' 'off,' 'up' and 'down,' which are used in standard speech recognition tests for electronic devices."

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A lot can happen over a good cup of coffee

Jaap Kistemaker's legacy: the morning coffee break where collegues at AMOLF meet daily and exchange thoughts and ideas, leading to top notch science.

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