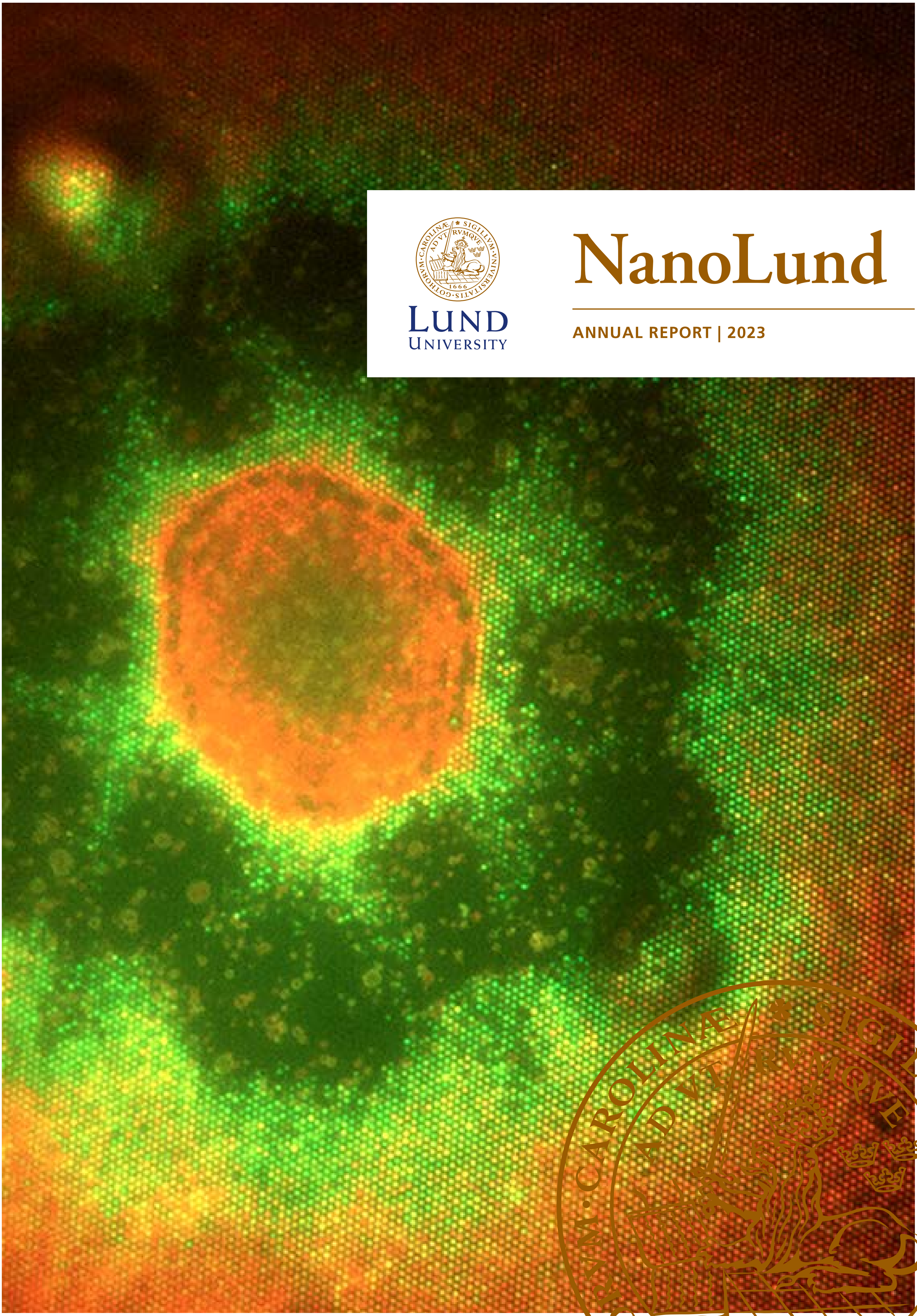


Lund University

NanoLund

ANNUAL REPORT | 2023

2023 in brief

RESEARCH AREAS

- Materials & Manufacturing
- Quantum Physics
- Semiconductor Technology
- Photons
- Life Science & Nano
- Nanosafety

KEY RESOURCE AREAS

- Lund Nano Lab
- Lund Nano Characterization Labs
- Education & Outreach

THE YEAR IN NUMBERS

425 number of people engaged in NanoLund

279 MSEK funding

66% from external funding sources

36 contributing LU divisions

35% of staff are women

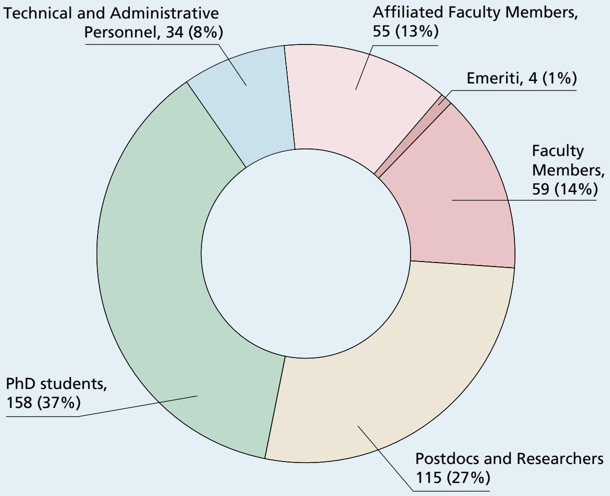
59 Faculty Members

55 Affiliated Faculty Members

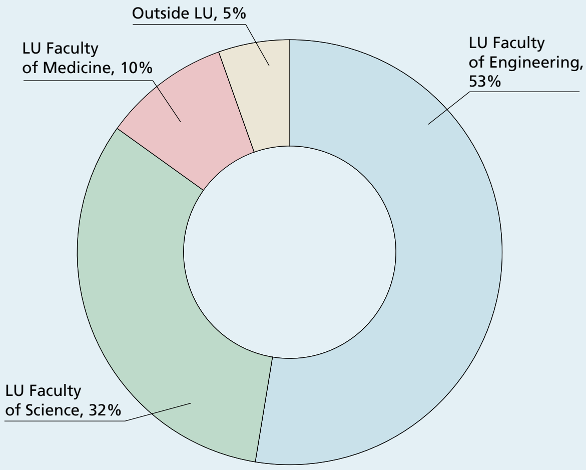
158 PhD students

150 undergraduate student members

NANOLUND PER PERSONNEL CATEGORY



FACULTY AFFILIATION



MAJOR GRANTS AND DISTINCTIONS

21 recipients of European Research Council (ERC) awards

4 Wallenberg Scholars

3 Distinguished professors, Swedish Research Council

17 ongoing EU-projects

9 ongoing Wallenberg projects, Research environment grants from the Swedish Research Council and Vinnova Competence Centres

PUBLICATIONS

462 publications in total

6.98 average impact factor

477 co-publishing intenational institutions

41 co-publishing companies

Making a mark in a big, expanding community

Photo: Johan Persson

Once again, we witnessed increased attention on NanoLund research and resource areas, both in Sweden, Europe, and worldwide. Working in some of the most competitive areas of science with new research centres and initiatives emerging constantly, it is impressive to see our impact. In all areas we achieved excellent, noticeable basic and applied research results in 2023.

Semiconductors and quantum technology received significant attention, not least with the European Chips Act and conferences such as the EuroNanoForum that we hosted. Materials Science & Manufacturing were in focus, in Sweden and internationally, being central to making our society more sustainable. We now have three major Swedish competence centres together with industry and got several new ERC grants for fundamental science.

For the area of Photons, the Nobel prize awarded this year to Anne L'Huillier in physics was a special highlight for many people, inspiring new ideas and collaborations, as we experienced at the meeting of Light and Materials. This is also a great encouragement for those of us developing new methods, it has the highest scientific value.

Health is a major priority in NanoLund, and our areas of Life Science & Nano and Safety have seen remarkable fundamental and applied results, where collaborations across many disciplines and sectors going well beyond NanoLund come into play.

For all our areas, modelling and AI are increasingly important. This is combined with our excellent infrastructures for studying and creating nanostructures. We sometimes forget how fortunate we are in Lund to have such amazing resources and how crucial they are. We are grateful for the great support in renewing these, most notably for Lund Nano Lab. The plans to establish a comprehensive presence in Science Village will be a major step for future competitiveness.

Finally, we observe a strong societal demand for the competencies we develop, our great PhD and undergraduate students are likely the most enduring outcome of all our work.

A big warm thanks to all staff, students, and partners, inside and outside the University, for your ongoing support, understanding and contributions. We all work together to make NanoLund a great place to conduct research, educate and make a difference in society.

Anders Mikkelsen | Director NanoLund

This is NanoLund

NanoLund is the centre for research, education and innovation within nanoscience and nanotechnology at Lund University. NanoLund was founded in 1988 and is a strategic research area funded by the Swedish Government.

NanoLund encompasses research groups at the faculties of engineering, science and medicine at Lund University as well as collaborators outside the University. It is Sweden's largest research environment in its field. The research topics range from materials science and quantum physics to applications in energy, electronics and semiconductors, photonics, life science and nanosafety.

Our research is organised in sub-areas to realise NanoLund's vision to be a world-leading research centre that uses the unique opportunities offered by nanoscience to advance fundamental science and to address societal challenges.

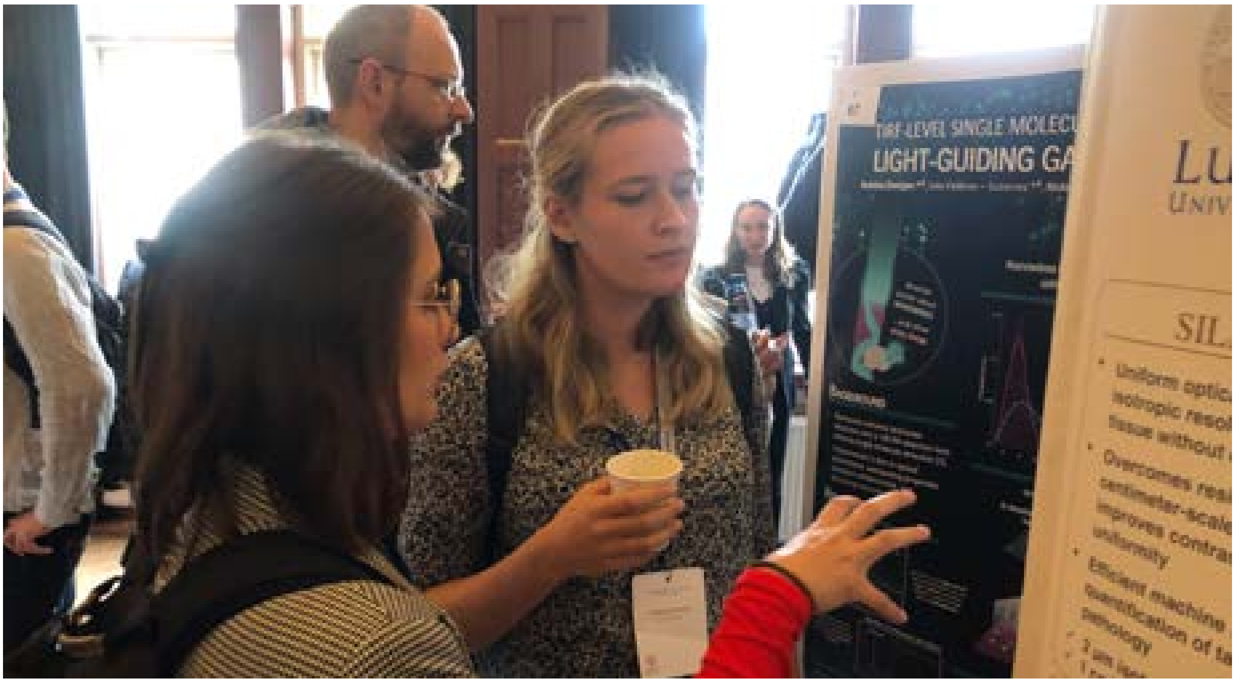
OUR RESEARCH:

MATERIAL SCIENCE AND MANUFACTURING provide the physical basis for much of our fundamental research as well as technologies for future industrial production. We aim to relate the atomic structure to the properties of a material and understand when and how nanostructures form and what structure to expect. Even very small changes in formation conditions can cause dramatic changes in the resulting nanostructure, and a challenge is to detect and control these. Our key expertise is in solid-phase nanostructures fabricated from the vapor phase, especially compound semiconductors and metal low dimensional structures. To ensure the development of high-quality nanostructures, experiments is combined with theory and simulations to warrant a fundamental understanding of the material formation process. We use advanced, often in-situ, techniques to characterise the nanostructures and continuously develop new processes and applications.

SEMICONDUCTOR TECHNOLOGY is vital for future communication systems, energy efficiency within both electronics and electrification, and for improving renewable energy sources and autonomous systems. We strive to find new ways of designing and implementing high-performance electronics on the nanoscale. Smaller device geometries lead to higher operation frequencies, larger small-signal gain, and better packing density. Wide bandgap semiconductors show a strong promise for the power converters that are critical in the electrification of society. Nanoscale field-effect transistors with narrow bandgap materials can realise and explore the high-frequency performance towards THz. Optoelectronic devices are developed for high-performance solar cells, light-emitting diodes and photodetectors. Device design is explored in the atomistic limits to push performance to extreme levels, and we work towards functional integration on silicon and silicon complementary metal–oxide–semiconductors (Si CMOS).

QUANTUM PHYSICS is where we develop the theoretical tools to better describe quantum phenomena, work to experimentally observe them, and then identify advanced device concepts where quantum effects enable better performance. In nanostructured systems, pronounced quantum behaviour gives rise to exciting new fundamental physics as well as potential applications.
The superposition of states and entanglement open completely new perspectives for sensing and communication technology. We explore novel quantum states in many- and few-body systems, photons interacting with quantum systems, and superconductor-semiconductor hybrid structures. Quantum thermodynamics develops new paradigms for energy conversion and quantum devices at the nanoscale, where thermal and quantum fluctuations may conspire to profoundly alter the physical properties and lead to fundamentally new physics.

PHOTONS assembles research on light-matter interactions in nanoscale materials and includes experimental and theoretical research where electromagnetic radiation from microwaves to X-rays is used as a probe, generated or absorbed by the material. We employ a broad range of methods, from basic spectroscopic techniques to combinations of time- and spatially-resolved probes, and different phenomena are harnessed, such as absorption, photoluminescence, electroluminescence and scattering. We study light-triggered exciton and charge carrier dynamics in a variety of nanostructures, use X-rays for locally probing



During the poster sessions of our annual meetings, participants can meet and discuss across the research areas. Photo: Evelina Lindén

the structural or electronic properties of semiconductors and catalytic centres, investigate photophysical properties of individual nanostructures, and model interactions between light and nanostructured semiconductors, as well as interactions in complex materials.

LIFE SCIENCE AND NANO utilise our capabilities to create structures on the relevant length scales for cells and molecules for fundamental studies in novel areas and for biomedical applications in areas where there are urgent needs for better functioning tools within research and health care. We strive for a detailed understanding of the interactions between cells and nanostructures concerning cell behaviour, physiology and mechanics. This knowledge will allow us to develop novel nanoscale tools with applications in biology and medicine. For example, nanoscale devices that can interact with cells with minimal perturbation or single-molecule sensitivity; injection, nanobiopsy, mechanosensing, or nanostructured tools that can control the cell behaviour with respect to differentiation, migration, proliferation and stimulation. We work for translation of results into applications in biophysics, brain science, diagnostics and personalised therapy.

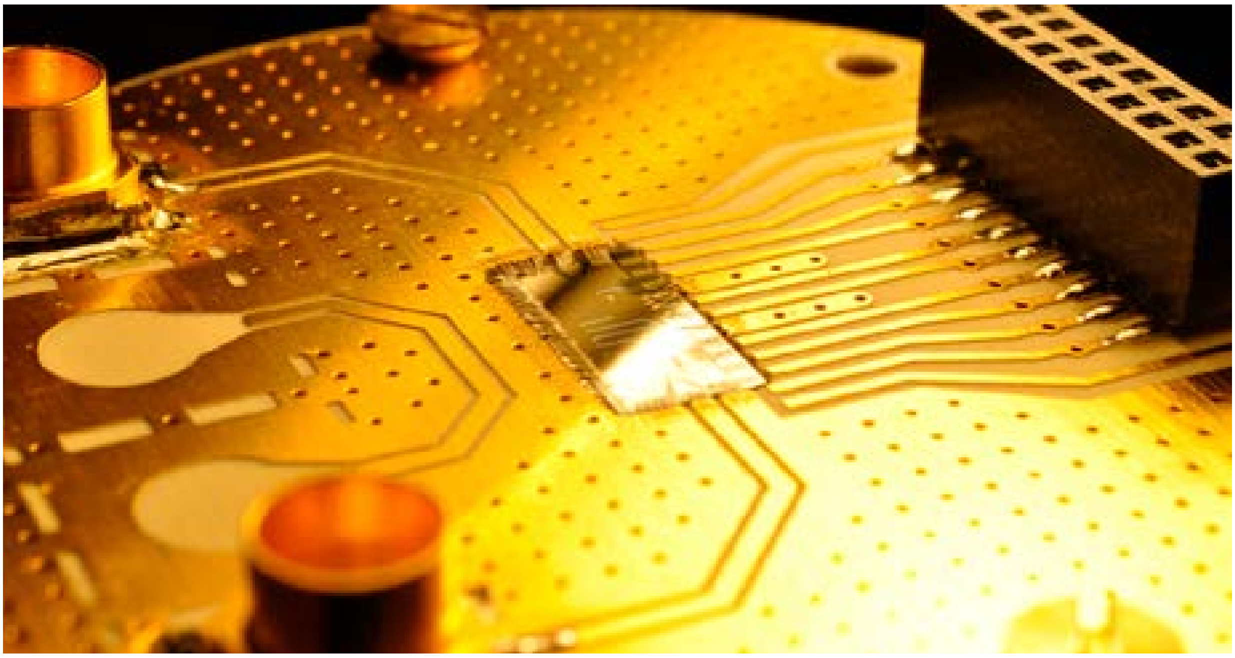
NANOSAFETY explores the fundamental connections between nanostructure properties and human and environmental toxicology, as well as emissions and exposure in all stages of the lifecycle of a nanomaterial, helping to provide the tools needed for safer design development and production of novel materials.

Emissions and exposures are studied with state-of-the-art instruments both in workplace environments and in controlled laboratory settings. The toxicological effects are studied on all levels: single cells, organisms, and ecosystems using various in-vitro, ex-vivo, and in-vivo methods. Safe production and use of nanomaterials require knowledge of nano-related toxicity as well as effective risk management ranging from legislative and regulative levels down to hands-on work processes.

SOCIETAL CHALLENGES WE AIM TO ADDRESS:

- **Enabling a sustainable society.** Paradigms and technologies for efficient harvesting and use of energy, and for nanomaterial-based products that are sustainable and safe from a life-cycle perspective.
- **A pathway to the future information society.** New physical concepts, smart materials, nanoscale devices, sensors and their heterogeneous integration to enable next-generation information technology.
- **Precision medicine.** Nano- and microstructures for biomedical research at the single-cell level and for fast point-of-care diagnostics, enabling targeted, individualised therapy.
- **Interaction with business and society.** Collaboration with the private and public sectors both locally and internationally. Jointly we can address sustainable development goals, help solve societal challenges, and create new industry.

Looking back at highlights of the year



A circuit board with a microwave photodiode to be used to make detectors that can identify microwave photons. Photo: Waqar Khan

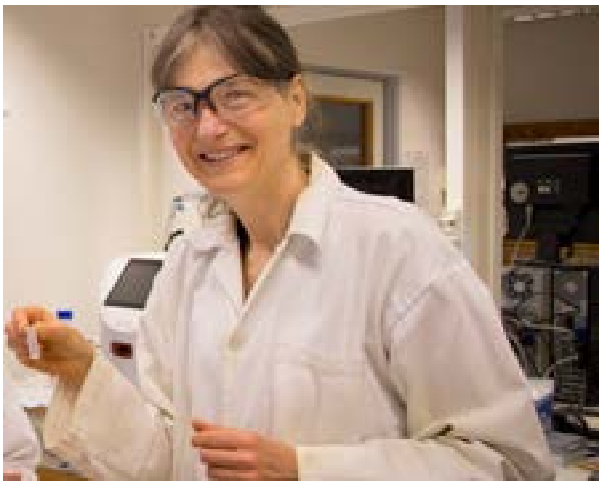
MEASUREMENT OF MICROWAVE PHOTONS COULD REVEAL MYSTERIES OF THE UNIVERSE

Ville Maisi has been awarded a European Research Council Consolidator Grant worth SEK 28 million for the QPHOTON project. The research will focus on building microwave detectors over a five-year period, involving the design of ultra-sensitive sensors that can measure and count microwave photons and thus provide new insights into how measurement processes work in small nanoscale systems.

"Traditional technology based on classical physics cannot perform certain calculations or provide sufficiently sensitive sensors for the most demanding measurements. The detection of microwave photons opens up new application areas in quantum technology through the improved sensitivity and new functionality of the detectors," Ville Maisi says.

The study described in the article below, Energetics of Microwaves Probed by Double Quantum Dot Absorption, tells us the story of a microwave version of the photoelectric effect.

Haldar, S. et al
Phys. Rev. Lett. 130, 087003 (2023)
https://doi.org/10.1103/PhysRevLett.130.087003



Sara Linse is awarded the European Research Council Advanced Grant. Photo: Johan Joelsson

ERC GRANT FOR FIGHTING NEURODEGENERATIVE DISEASES

Sara Linse has been awarded the ERC Advanced Grant worth EUR 2.5 million to further develop and advance her project, that concerns research on chaperone proteins' function in neurodegenerative diseases such as ALS, Huntington's, Alzheimer's, Parkinson's, and type 2 diabetes.

"It is immensely pleasing and flattering. The ERC grant enables us to take an in-depth approach using this exciting research, develop new methodologies, and collect data in a systematic way. I hope that after five years we will be close to an answer to the fundamental question," says Sara Linse, professor of biochemistry and structural biology.

Welding, and whether new methods can be used to weld advanced alloys is in focus for the project for which Filip Lenrick has been awarded an ERC Starting Grant. Photo: Klas Holger Jönsson

WELDING HIS WAY TO AN ERC STARTING GRANT

Filip Lenrick, a researcher in industrial production, has received EUR 1.5 million over five years for the project "Bulk-like Joints by Gas Actuated Bonding".

"My research is in the area of materials science and method development for industrial conditions. Often it is about using academic tools, such as microscopes or models, on industrially formulated questions. Sometimes it is about taking advantage of expertise or equipment available in companies to get closer to an answer to academic questions.

The ERC project will deal with welding, and whether new methods can be used to weld advanced alloys, such as complex steels. Since I have a background in so-called microfabrication technology, i.e. the technology for manufacturing semiconductor and nanocomponents, I will investigate whether welding can be carried out with the equipment available at Lund Nano Lab. The same equipment that is usually used to manufacture LEDs, transistors, and solar cells" says Filip Lenrick, who aims to develop a method that is capable of welding the advanced alloys needed for the next generation of energy systems, such as solid oxide fuel cells or thermal solar power stations.

"These applications create an extremely stressful environment for the materials used in the equipment. There are large forces at high temperatures in a corrosive environment, all at the same time. Therefore, very advanced alloys will be required for equipment to function. The problem is that such alloys are generally difficult or impossible to weld. I want to solve this by developing a new way of welding."

FLUORESCENCE EXCITATION ENHANCEMENT BY WAVEGUIDING NANOWIRES

The optical properties of vertical semiconductor nanowires can allow an enhancement of fluorescence from surface-bound fluorophores, a feature proven useful in biosensing. One of the contributing factors to the fluorescence enhancement is thought to be the local increase of the incident excitation light intensity in the vicinity of the nanowire surface, where fluorophores are located. However, this effect has not been experimentally studied in detail to date. In this study, researchers quantified the excitation enhancement of fluorophores bound to a semiconductor nanowire surface by combining modelling with measurements of fluorescence photobleaching rate, indicative of the excitation light intensity, using epitaxially grown gallium phosphide (GaP) nanowires. The results can be used to design nanowire-based optical systems with exceptional sensitivities for bioanalytical applications.

Unksov, I. et al

Nanoscale Adv., 2023, 5, 1760.

https://pubs.rsc.org/en/content/articlelanding/2023/na/d2na00749e

NEW MENTORING PROGRAMME

Twelve PhD students were matched with mentors in the pilot-round for a new mentoring programme, to guide the students and open new networks for them.

The NanoLund mentoring programme has been established to provide young researchers with independent support and guidance as they navigate their career paths. The ambition is to allow program participants to discuss their professional opportunities, ambitions and challenges together with an independent mentor from outside the research group, and often outside academia.

The NanoLund mentoring programme kicked off with 12 PhD students meeting Tina Persson, a Global ICF Coach. Photo: Mirja Carlsson Möller

BALANCING WORK AND LIFE AT THE NANOLUND STUDENT AND POSTDOC RETREAT

The NanoLund Student and Postdoc retreat took place in Smygehamn with almost 70 participants. They used the opportunity to dive into the topics "Work-Life-Balance" and "Communication" during the two days at the idyllic south coast of Skåne with speakers sharing their expertise, interactive workshops, and a social program.

Linda Kuhn, a psychologist at the occupational health service of Lund University provided insights and food for thought. Postdoc Stephanie Matern led an interactive workshop about life as a researcher. Under the topic of "Communication", Marie Jönsson and Alexis Luis from Lund Stem Cell Center provided great insights into giving interesting and engaging scientific presentations and aspects of written communication in the form of grant writing.

The NanoLund annual student retreat is a popular event, gathering students, PhD students, and postdocs from NanoLund. Photo: Nils Gustafsson

Axl Eriksson, PhD student, shows the new spectrometer developed at the Department of Chemistry at Lund University. Photo: Jens Uhlig

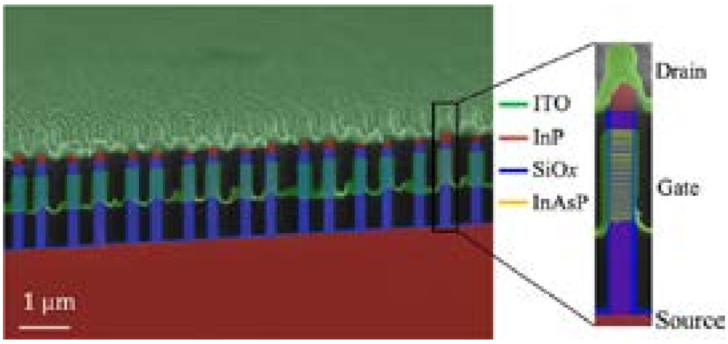
INEXPENSIVE SPECTROMETER TRIGGERS CHEMISTRY STUDENTS' CURIOSITY

A team of NanoLund researchers sought ways to make students understand what is actually happening inside the "magic black box" of a commercial spectrophotometer.

"This set promotes discovery in a natural and self-motivating way. By changing samples in the spectrometer, we can explore a variety of materials and their properties," says Jens Uhlig, NanoLund education coordinator, chemistry researcher and one of the researchers behind the work.

"Science is more interesting if it is related to our everyday life and is easily accessible. Our new spectrometer, therefore, consists of inexpensive components and minimal theory. It encourages students' curiosity to solve problems and understand how a spectrometer works," says Jens Uhlig.

Kolesnichenko, P. et al
J. Chem. Educ. 2023, 100, 3, 1128–1137
https://doi.org/10.1021/acs.jchemed.2c00679



NOVEL HIGH-PERFORMANCE NANOWIRE PHOTOTRANSISTORS WITH TUNABLE PHOTORESPONSE

High-performance broadband photodetectors offering spectral tuneability and a high gain-bandwidth product are crucial in many applications such as optical communication and biomedical imaging. This study reports on a detailed experimental and theoretical study of three-terminal phototransistors comprised of three million indium phosphide nanowires with 20 embedded indium arsenide phosphide quantum discs in each nanowire.

The results pave the way for a new type of gate-controlled phototransistor, potentially compatible with main-stream silicon technology due to the small footprint of the nanowires.

Jeddi, H. et al

ACS Photonics. (2023) 085003

https://doi.org/10.1021/acsphotonics.2c02024

ELECTROTHERAPY WITHOUT SURGERY

Bioelectronics can potentially complement classical therapies in temporary treatments, such as immunotherapy and cancer. Bioresorbable materials are central to nonchronic treatments and removes the need for surgical removal after disease relief. In this study, researchers place bioresorbable electrodes with a brain-matched shear modulus – made from water-dispersed nanoparticles in the brain – in the targeted area using a capillary thinner than a human hair. Roger Olsson, professor of chemical biology and therapeutics, and Martin Hjort, researcher in chemical biology and therapeutics, have together with researchers at Gothenburg University successfully developed temporary, organic electrodes that can be seamlessly integrated into biological systems. The method, described in the article "In situ assembly of bioresorbable organic bioelectronics in the brain", opens up a future where bioelectronics can be implanted into and removed from the body without surgery.

Hjort, M. et al

Nature Communications 14, 4453 (2023)

https://doi.org/10.1038/s41467-023-40175-3

WISE – MAKES IT POSSIBLE TO CONSOLIDATE EFFORTS IN MATERIALS SCIENCE

The Wallenberg Initiative Materials Science for Sustainability, WISE, is the largest-ever investment in materials science in Sweden and is financed by the Knut and Alice Wallenberg Foundation. Lund university plays an important role in the initiative.

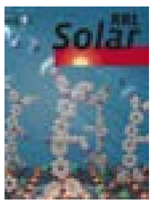
"During 2023, the programme has really kicked off and we've recruited both academic and industrial doctoral students and postdocs as well as two associate senior lecturers. Many NanoLundians have been successful in getting funding by WISE", says Anders Mikkelsen.

The need to develop robust energy systems based on renewable energy sources is urgent, and solar energy defines a competitive opportunity with short energy payback time. By harnessing solar power in a smart way, we can effectively meet future energy needs. However, unlocking its full potential requires significant advancements in the process of clean energy generation, including how we collect, convert, and store it.

One important piece of the puzzle is solar panels. These devices consist of solar cells made from materials that generate free charge carriers when exposed to sunlight, that are finally collected to produce an electric current. One of the promising materials, known as semiconductor halide perovskite, is pivotal for future technologies to convert sunlight into electricity.

The first published scientific article in the WISE programme is written by NanoLundian Maning Liu et al. They investigate how to significantly improve the performance and stability of the solar cells.

"Eventually, we found that twisted side-chains in the small molecular hole-transport materials are more favourable for the efficient interfacial charge transfer as well as for blocking the diffusion of hygroscopic dopants towards perovskites, leading to much-enhanced device performance (almost doubled efficiency compared to the planar case) and operation stability," says Maning Liu.



Li, R. et al

Solar RRL, Volume7, Issue18

https://doi.org/10.1002/solr.202300367

NanoLund Director Anders Mikkelsen, Veronica Lattanzi who did her PhD at NanoLund, and Peter Dröll from the European Commission during coffee break at the EuroNanoForum 2023. Photo: Evelina Lindén

THE IMPORTANCE OF TAKING NANOSAFETY INTO ACCOUNT

Lung exposure to gallium phosphide nanowires induces an inflammatory response and allergic response when tested on mice. Even if the nanowires underwent partial dissolution in the lung, resulting in thinner nanowires, they were detected in lung, liver, spleen, kidney, uterus and brain three months after exposure.

"This emphasises how important it is that we continue to take nanosafety into account", says Professor Christelle Prinz, one of the researchers behind the study.

"By combining many experimental methods, we could investigate the inflammatory and allergic responses elicited by nanowires, as well as track and characterise the nanowires in lungs and distant organs. The study also shows the relevance of using nanowires as models for one-dimensional nanoparticles, since they are easy to localise in tissue, using electron- and optical microscopy", says Christelle Prinz.

Berthing, T. et al
Journal of Nanobiotechnology, 2023, 21:322,
https://doi.org/10.1186/s12951-023-02049-0

EURONANOFORUM BROUGHT TOGETHER ACADEMIA, INDUSTRY, POLICYMAKERS, AND STAKEHOLDERS

The international conference EuroNanoForum 2023, funded by the EU and Vinnova, and organised by NanoLund together with Chalmers, brought together leading scientists, innovators, representatives from industry, and policymakers from Europe, USA, and China to discuss ground-breaking research and foster collaboration. It gathered almost 400 participants, including the Swedish Minister of Education Mats Persson, the Director General of Vinnova Darja Isaksson, and Peter Dröll, Director for Prosperity, Directorate-General for Research and Innovation at the European Commission. Topics concerned materials for a sustainable future, advanced materials for aerospace, solar hydrogen, electrochemical energy storage, quantum computer ecosystems, life sciences – and the greenest battery on earth.

https://www.nano.lu.se/euronanoforum

PRECISE TUNING OF METAL-HALIDE PEROVSKITE NANOWIRES

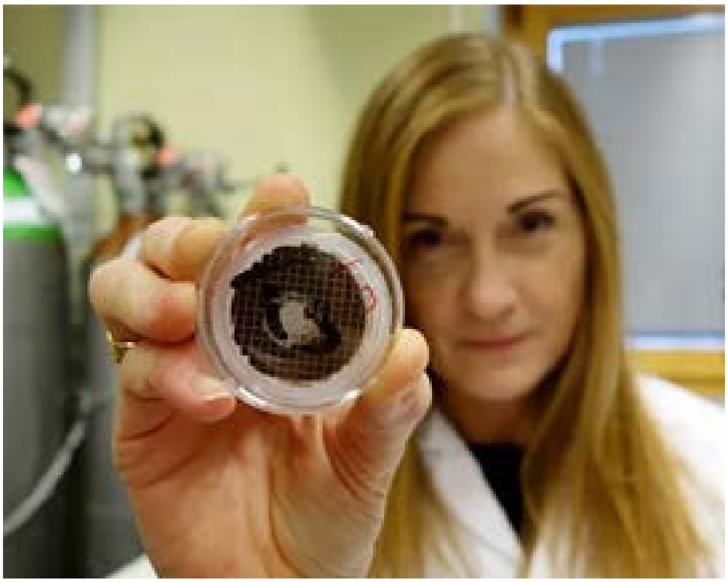
Anion exchange allows post-growth tuning of metal-halide perovskites (MHPs) band gaps and crystal structure. In this study, we demonstrate halide substitution in cesium lead bromide nanowires using chlorine gas. Segments as short as 500 nm are achieved through lithographic patterning. The possibility of designing heterostructures will be important for device applications of MHPs.

Lamers, N. et al
Adv. Opt. Mater, 2023, 2300435
https://doi.org/10.1002/adom.202300435

CHRISTINA ISAXON DISCUSSED AIR POLLUTION IN ALMEDALEN

At the annual event Almedalen Week, Lund University highlighted our global challenges – such as air pollution and food poverty. Christina Isaxon, aerosol researcher at the Faculty of Engineering (LTH), participated in a panel discussion named "Clean air for everyone?" and an interview organised by the think tank "Humtank" on how collaboration between the humanities and technology may contribute to better global health. She hopes for the discussions to help finding common paths forward:

"As a researcher, I am interested in what is required for us to comply with the air pollution maximum levels and how research can contribute."



"The air does not recognise national borders. Much of the air pollution we are exposed to in southern Sweden actually emanates from entirely different parts of the world," says Christina Isaxon. Photo: Erik Andersson

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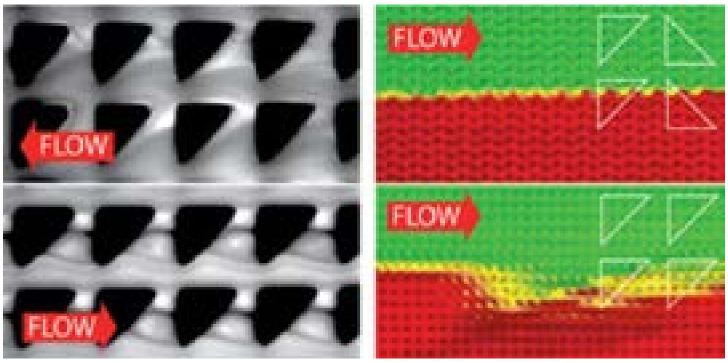


"We were surprised by how nicely the symmetry break of the pillars on the micrometre scale was reflected in the overall behaviour of the waves on the millimetre scale," says Jonas Tegenfeldt. Picture from the study

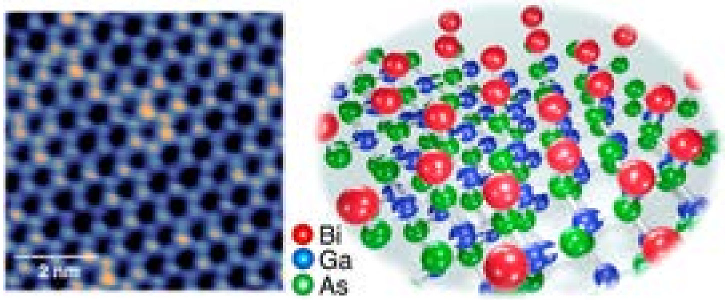
CONTROLLING VISCOELASTIC WAVES USING SYMMETRY

First, they discovered how DNA can move in wavelike patterns on the millimetre scale in microfluidics devices – now they have also found a way of controlling the behaviour. Four researchers connected to NanoLund have presented results that may be useful in several ways: to enhance or suppress the microfluidic mixing, relevant for medicine and food industry as well as water treatment.

Beech, J. P. et al
RCS Advances 2023, 13, 31497-31506
https://doi.org/10.1039/D3RA06565K

HONEYCOMB SURFACE STRUCTURE ENABLES NEXT-GENERATION DESIGN OF DEVICES

A new bismuth-induced surface structure has been discovered on gallium arsenide, GaAs(111), a semiconductor widely used in electronics and optics. Structurally, it looks like bismuthene, but the bismuth atoms form covalent bonds to the substrate underneath.



The structure is characterised by low-temperature scanning tunnelling microscopy and spectroscopy, and X-ray photoelectron spectroscopy at MAX IV. Density functional theory calculations predict a large nontrivial band gap, which is a requirement for room-temperature spintronic applications. This enables the development of a next-generation design of devices, directly integrating spintronic applications of two-dimensional topological insulators with well-established (opto-)electronic semiconductor technology.

Liu Y. et al
ACS Nano 17, 5047 (2023)
https://doi.org/10.1021/acsnano.2c12863

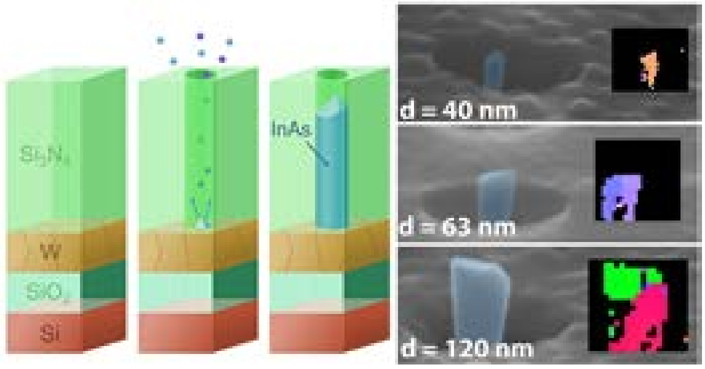
GUIDING THE GROWTH OF NANOWIRES ON TUNGSTEN

This work demonstrates for the first time controlled indium arsenide nanowire growth onto tungsten metal, opening for the realisation of 3D chips that integrate III-V electronic and optoelectronic devices into the CMOS (Complementary Metal-Oxide-Semiconductor) back-end. Bringing high-mobility III-V semiconductor devices into back-end-of-line processing, opens for new possibilities in 3D integrated optoelectronics and high-frequency communication and may potentially lead to more compact, efficient, and high-performance electronic systems.

Svensson J. et al

Nano Lett., 2023, 23, p.4756-4761

https://doi.org/10.1021/acs.nanolett.2c04908



EXPLORING EXCITONIC DYNAMICS

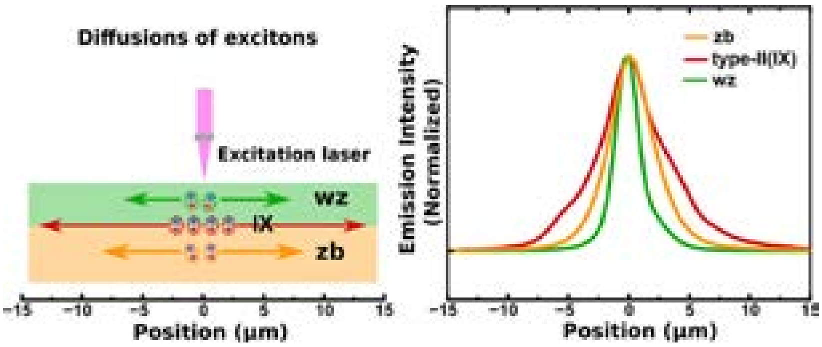
In this extensive study of indirect excitons (IXs) bound to the type II interface between an indium phosphide (InP) zinc blende substrate and InP wurtzite platelets, the IX emission shows a significant blue shift with increasing excitation power and exhibits long emission times (tens of microseconds). The IXs also show significant transport away from the excitation spot at high excitation power caused by Coulomb repulsion, rather than diffusion.

The investigation provides a better understanding of the recombination dynamics and spatial distribution of IXs. It opens up the possibility of studying phenomena such as exciton condensation at type-II polytype interfaces and exploring the features required for excitonic devices.

Jash, A. et al

ACS Photonics 2023, 10, 3143

https://pubs.acs.org/doi/full/10.1021/acsphotonics.3c00517



ULLA VOGEL AWARDED HONORARY DOCTORATE

Ulla Vogel, head of Nanotoxicology and Occupational Hygiene at the National Research Centre for Occupational Health and Safety in Copenhagen, is one of the international experts that we have had the pleasure of seeing as members in the NanoLund Scientific Advisory Board. 2023 she was awarded an honorary doctorate from Lund University Faculty of Engineering, LTH, since she is a role model in taking basic and applied research to societal impact and improved legislation.

Photo: NIVA

The millimetre-sized chip on which the transistors are located. Photo: Anton Persson

CUTTING EDGE TRANSISTORS FOR SEMICONDUCTORS OF THE FUTURE

Transistors that can change properties are important elements in the development of tomorrow's semiconductors. With standard transistors approaching the limit for how small they can be, having more functions on the same number of units becomes increasingly important in enabling the development of small, energy-efficient circuits for improved memory and more powerful computers.

Reconfigurable transistors are an emerging device technology adding new functionalities while lowering the circuit architecture complexity. However, most investigations focus on digital applications. This study demonstrates a single vertical nanowire ferroelectric tunnel field-effect transistor (ferro-TFET) that can modulate an input signal with diverse modes including signal transmission, phase shift, frequency doubling, and mixing with significant suppression of undesired harmonics for reconfigurable analogue applications. The ferro-TFET shows merits of reconfigurability, reduced footprint, and low supply voltage for signal modulation. The work described in the article "Reconfigurable signal modulation in a ferroelectric tunnel field-effect transistor" provides the possibility for monolithic integration of both steep-slope TFETs and reconfigurable ferro-TFETs towards high-density, energy-efficient, and multifunctional digital/analogue hybrid circuits.

Zhu, Z. et al
Nature Communications 14, 2530 (2023)
https://doi.org/10.1038/s41467-023-38242-w

Successful annual meeting together with Light and Materials

Photo: Evelina Lindén

At the Synergy Day 2023, 250 researchers from Lund Laser Centre and NanoLund together with MAX IV Laboratory met under the umbrella of Lund University's profile area Light and Materials for an entire day. Nanowires, quantum dots, lasers, and much more were discussed, and we also enjoyed an acclaimed presentation from Nobel Laureate Anne L'Huillier. The programme was put together by the organising committee consisting of Christelle Prinz, Francesca Curbis, Joakim Bood, and Tönu Pullerits.

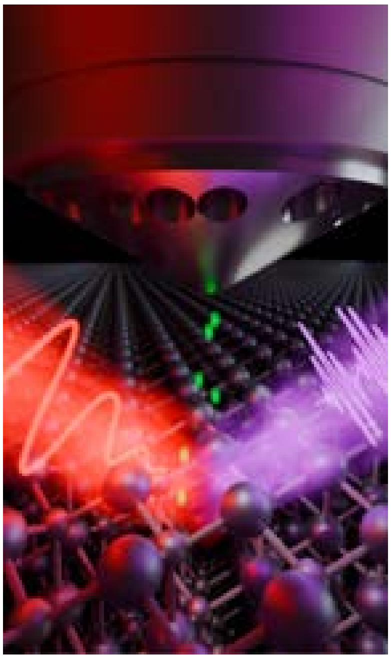
The Nobel prize has finally been awarded to a Lund University scientist

For experiments having given humanity new tools for exploring the world of electrons inside atoms and molecules, the Nobel Prize in Physics 2023 was awarded Anne L'Huillier, professor of Atomic Physics at LTH, jointly with Pierre Agostini and Ferenc Krausz. NanoLund is proud and humbled to have an excellent researcher like Anne L'Huillier in its research environment.

"We can now open the door to the world of electrons. Attosecond physics allows us to understand mechanisms that are governed by electrons. The next step will be utilising them," says Eva Olsson, Chair of the Nobel Committee for Physics.

There are potential applications in many different areas. In electronics, for example, it is important to understand and control how electrons behave in a material. Attosecond pulses can also be used to identify different molecules, such as in medical diagnostics.

The laureate herself was in the middle of lecturing students in atomic physics, when her phone started to buzz. During a scheduled break, she got the announcement from the Royal Swedish Academy of Sciences.



OPENING UP FOR A DETAILED UNDERSTANDING OF NANOMETRIC LIGHT-MATTER INTERACTION

In a recent study, Jan Vogelsang, Lukas Wittenbecher, Sara Mikaelsson, Chen Guo, Ivan Sytcevich, Anne-Lise Viotti, Cord L. Arnold, Anne L'Huillier, and Anders Mikkelsen demonstrates a clear pathway for attosecond interferometry with high spatial resolution at atomic scale surface regions.

A pair of extreme ultraviolet attosecond pulses photoemits electrons from the surface of a zinc oxide crystal, while experiencing the field of a time-delayed, near-infrared (NIR) probe pulse. The photoelectrons are recorded with a photoemission electron microscope (PEEM), resulting in spatially resolved attosecond interferometry. This is the first time photoelectron cross-correlation traces were recorded with a PEEM as detector. It is a step towards attosecond time-resolved and nanometre spatially resolved photoelectron emission time measurements.

Vogelsang J. et al
Adv. Physics Res. 2023, 2300122 (2023)
https://doi.org/10.1002/apxr.202300122

Stepping out to meet the cheering crowds at Fysicum celebrating the announcement from the Royal Swedish Academy of Sciences, Professor of Atomic Physics Anne L'Huillier is shrouded in jubilation. Her discovery: a method to generate unbelievably short light pulses that can "photograph" electrons and provide us with new insights into the inner life of atoms.
Photo: Luke Hankin

Heiner Linke, Professor of Nanophysics, chair of the NanoLund Board and member of the Nobel Committee, presented the Nobel Prize in Chemistry. He used his fingernails to illustrate and explain the concept of quantum dots – nanoparticles so tiny that their size determines their properties.

"If particles were made small enough to squeeze together the electron's quantum waves, the electron should be able to store more energy, and then release it to a bright photon. Larger particles would make red light, and smaller particles blue light."
Photo: Nobel Prize Outreach AB / SVT

Collaboration and innovation

Our vision is to apply cutting-edge nanotechnology to address societal needs. To reach that goal NanoLund works to support collaboration and innovation. By engaging together with companies and societal actors, we can contribute with new technology. This means that we aim for collaborations in innovation and development areas where research and knowledge within NanoLund can be part of a solution.

We strive to develop long-term collaborations with stakeholders in industry, institutes and society within all our research areas. In 2023 Vinnova decided to fund two new centres of excellence coordinated by NanoLund researchers in the areas of sustainable industry and digital social transition. NanoLund researchers are thus now engaged in three long-term centres cofunded by Swedish industry (large companies, small and medium sized companies and sectorial organisations) as highlighted on the next page. We also continue to see an increase in co-publications of scientific results with industrial partners. Currently four industrial PhD students are doing their doctoral education within NanoLund. Altogether this indicates that long-term partnerships bear fruit.

Researchers and students are encouraged to validate how their research results can be utilised for new concepts, ideas, and products of relevance to society and industry. We aim to support innovation activities in different ways and are very proud of all the companies spun out of NanoLund – as many as 31 companies since the start of the research centre in 1988.

Table 1. Spin-off companies from NanoLund
Spin-off companies from NanoLund (companies in operation by December 2023, in alphabetical order).
The number of employees has been deducted from the latest available public annual report (2022).

COMPANY		STARTING YEAR	NUMBER OF EMPLOYEES 2022
Acconeer	Develops radar solutions based on pulsed coherent radar technology combining extremely low energy consumption with high accuracy.	2011	49
AcouSort	Combines acoustics and microfluidics to separate and sort cells and particles in biological and clinical samples.	2010	14
Aligned Bio (previously AlignD Systems)	Utilises the light-guiding properties of semiconductor nanowires to develop a biosensor platform for analyzing biomarkers such as proteins and other molecules.	2019	8
AlixLabs	Provides a method to manufacture nanostructures with a characteristic size below 20 nm for the electronics industry.	2019	4
BrainLit	Combines light-emitting diode (LED) technology with knowledge about the effects of light on human anatomy and physiology for new in-door lighting.	2012	20
Cytely	Provides advanced research technology through data-driven microscopy within life sciences.	2022	No available data
Deep Light Vision	Develops a non-invasive method (Ultrasound Optical Tomography) using laser light for clinical diagnosis of for instance cancer or vascular disease.	2021	0
NordAmps (previously C2Amps)	Develops a new technology for transistors by combining the high performance of semiconductor materials (In(Ga)As-nanowires) with the economy of scale supported by silicon substrates.	2016	3
Cellevate	Provides the biotech industry with cell culture systems where cells are grown in a porous network of nanofibers mimicking different types of body tissues.	2014	7
Glo (acquired by Nanosys 2021)	Developed micro-LEDs in the colours red, green and blue using III-nitride-based nanowires.	2003	No available data
Hexagem	Develops wafers of the semiconducting material gallium-nitride using a new patented technology that completely avoids threading dislocations resulting in a material of higher quality.	2015	4
NeuroNano	Develops innovative electrodes for deep brain stimulation (DBS) with the aim of improving the quality of life for people with various neurological illnesses.	2006	6
Obducat	Develops and supplies lithography solutions for the production and replication of advanced micro and nanostructures for industrial needs.	1989	40
Spermosens	Develops a diagnostic technology for male infertility aiming to predict the outcome of in-vitro fertilisation.	2019	8
Watersprint	Develops and manufactures products for water purification using light-emitting diodes (LED) in the ultraviolet spectrum C (wavelengths ranging from 100 to 280 nm).	2013	8
WaveBreak (former Wren Therapeutics Ltd.)	Aims to discover and develop drugs for protein-misfolding diseases such as Alzheimer's and Parkinson's disease. The work is based on research on the chemical kinetics of the misfolding process.	2016	4 in Sweden

NANOLUNDIANS ON PRESTIGIOUS LISTINGS

The Royal Swedish Academy of Engineering Sciences (IVA) annual list of research projects with potential impact on society included no less than five NanoLundians: Ruby Davtyan, Fredrik Höök, Heiner Linke, Pontus Nordenfeldt, and Kenneth Wärnmark.

The projects concern image analysis for early disease detection, solar cells and large-scale fuel production with luminous iron, and data-driven microscopy. The theme this year was "Technology at the service of humanity in climate change, energy supply, societal wealth technologies, cybersecurity and crisis preparedness".

Also, two of our spin-off companies are on the magazine Ny Teknik's list of Sweden's 33 best, most innovative, and promising young technology companies: AlixLabs, providing atomic layer etching for nano device fabrication, and NordAmps, working with delivering the next generation of transistors.

INNOVATIONS SPRING FROM RESEARCH

The European Research Council Proof of Concept is granted to Christelle Prinz, Professor of Solid State Physics, and Anne L'Huillier, Professor of Atomic Physics. With €150,000 each, they will explore the innovation potential of their ERC frontier research project.

Christelle Prinz works on creating cost-effective biosensor diagnostics for the early detection of ovarian cancer, allowing doctors to identify women at risk of developing it, complementary to existing methods such as biopsies and transvaginal ultrasounds.

Anne L'Huillier and her group will develop a new compact device for characterizing ultrashort laser pulses in the project "SICEP, Single-shot, high repetition rate detection of the Carrier-Envelope-Phase of ultrashort laser pulses" in collaboration with a deep-tech company, Sphere Ultrafast Photonics, located in Porto, Portugal.

"The idea originates from a talented research engineer, Chen Guo, together with associate professor Cord Arnold", says Anne L'Huillier.

Photo: Thor Balkhed

CHIP TECHNOLOGY, NANOSENSORS AND POWER ELECTRONICS IN THE VINNOVA COMPETENCE CENTRES

New research environments for sustainable and digital transformation are emerging. Sweden's Innovation Agency, Vinnova, invests in 11 new competence centres starting in January 2024. Among those, two are directly connected to NanoLund – adding to the already existing centre C3NiT.

In the competence centres, universities and companies will jointly conduct excellent research and education in areas that are important for sustainable industry and digital social transformation. The goal is for new knowledge and ground-breaking technology to be developed, disseminated, and used to speed up the transition. The investment will also contribute to attracting cutting-edge expertise for world-leading research and development in Sweden with the aim to strengthen Sweden's competitiveness.

The three Vinnova Competence Centres connected to NanoLund are:

- ACT, Advanced Chip Technology – developing processes and methods for the development of semiconductor components. Director: Lars-Erik Wernersson.
- C3NiT, Centre for III Nitride Semiconductor Technology – a platform for cutting-edge research in III-nitride semiconductors for the next generation of power and high-frequency electronics, through a combination of scientific excellence and industrial relevance. Director: Vanya Darakchieva
- ISentio, Integrated Sensors and Adaptive Technology for Sustainable Products and Manufacturing – focusing on integrated sensor technology that enables digital real-time optimisation of industrial products and production processes for a sustainable industry. The centre will engage researchers across LTH with excellence in knowledge of the production industry, nanomaterial fabrication, in-operando characterisation with machine learning for adaptive control and statistical signal processing, software interfacing and process, cost and sustainability analysis. Director: Anders Mikkelsen.

Cutting-edge infrastructure

The scientific work done at NanoLund is enabled and complemented by our infrastructures, open research facilities and world-class clean rooms that contain state-of-the-art equipment.

Lund Nano Lab – the nanofabrication facility Myfab Lund is a key resource for nanoscience and nanotechnology at NanoLund. The clean room facility serves the needs of multiple research groups in strategically important fields. The infrastructure is continuously updated and is supported by a dedicated team of highly educated lab personnel. Lund Nano Lab (LNL) is also a node of the national infrastructure Myfab, whose mission is to provide Swedish researchers, entrepreneurs, and industry with leading-edge micro and nanofabrication facilities. Myfab has important collaborations and is part of the Nordic Nanolab Network (NNN).

Lund Nano Characterisation Labs is a distributed network of many characterisation laboratories within NanoLund ranging from microscopes capable of single-atom imaging to ultrafast spectroscopy laboratories that track processes on a femtosecond time scale.

nCHREM – the National Centre For High-Resolution Electron Microscopy offers instruments and expertise for imaging, analysis and sample preparation for a wide variety of sample types. State-of-the-art atomic-level imaging, element analysis, and sample preparation for hard materials, biological materials and liquids are performed. nCHREM provides electron microscopes for analytical high resolution work, surface imaging (SEM), cryo-TEM for sensitive samples and a unique environmental TEM where chemical reactions and crystal growth can be performed at high temperatures, while recording videos with atomic resolution, simultaneously with element analysis.

KEY FEATURES OF LNL

- Open clean room facility for micro- and nanofabrication, accommodating academic researchers and companies with 90+ bookable tools.
- Supporting materials synthesis, advanced processing, and characterisation for diverse multidisciplinary nanoscience research.
- Specialising in growth of compound semiconductors nanostructures such as nanowires, and with nanoelectronics, LED and solar applications.
- Supporting three Vinnova competence centres focused on addressing sustainability challenges in society and industrial manufacturing.

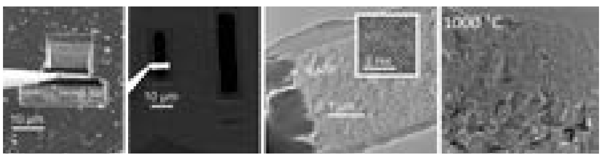
LNL NUMBERS IN 2023

283	Users with access
133	Active users
38	New users
38	Research groups
22	Company users
5	Research institute users
29 984	Booked hours

Valuable contributors to new advanced equipment
The Olle Engkvist Foundation, the Crafoord Foundation, Sparbanksstiftelsen Finn, LMK-stiftelsen, the Knut and Alice Wallenberg Foundation and the Swedish Research Council through Myfab.

USER CASE: MICROSCOPY OF THE CUTTING EDGE – MAKING CUTTING TOOLS RESILIENT

Coatings of titanium-aluminium nitride are used to protect metal cutting tools from oxygen at the high temperatures generated during their use. Their resilience stem from the slow transformation of aluminium in the coating to aluminium oxide, which is very hard in itself and prevents oxygen from diffusing into the underlying tool. Researchers from NanoLund in collaboration with SECO Tools have recently been able to image this reaction at atomic resolution and in real time using environmental transmission electron microscopy. For coatings with very high aluminium contents, the aluminium oxides were observed to form separate grains with cracks, rather than

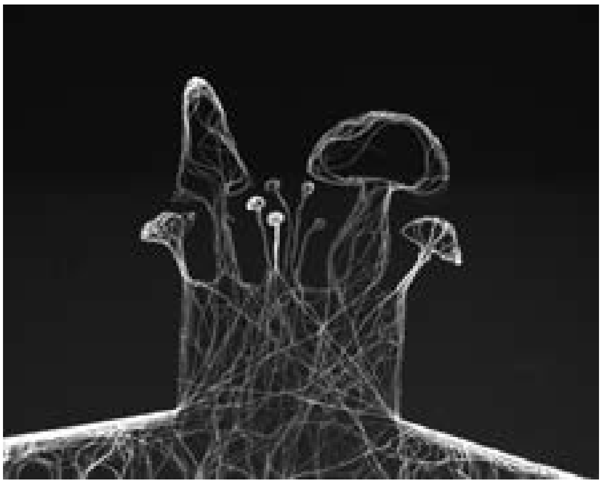


Removing a thin slice from an industrial cutting tool coating, and mounting it on a heating chip, allows atomic resolution imaging inside the environtmental transmission electron microscope. Separate titanium and aluminium oxides are formed above ca. 900 °C in air, which can actually protect the underlying tool.

the expected layer on the surface, as the temperature approached 1000 °C. This visualises for the first time the underlying reason for the reduced performance of high aluminium content coatings. Apart from the new insights into the performance of metal cutting tools, these techniques are promising for a range of bulk, but nanostructured, materials that are exposed to high temperatures and reactive environments. For instance, this could be relevant for corrosion and studies of metal joining processes.

Martin Ek Rosén

Makgae O. A. et al
Applied Surface Science 618, 156625 (2023),
http://dx.doi.org/10.1016/j.apsusc.2023.156625



A fungal hyphae (mycelium) with fluorescence in a microfluidic channel. Photo: Hanbang Zou and Edith Hammer

USER CASE: THE ROLE OF FUNGI IN ECOSYSTEMS

We produce microfluidics technology-based microstructured chips by pouring PDMS on masters, fabricated at Lund Nano Lab by photolithography on Si wafers. The chips serve as habitats for soil and laboratory-cultured microbes inoculated within and can be set up at a structural and chemical complexity level which allows mimicking real soil.

Biotic interactions in soil affect fungal behaviour through a series of manipulative experiments in microfluidic chips. By better understanding fungal sensory biology and elucidating what causes changes in fungal behaviours we can learn more of the role fungi play in soil ecosystems and gain valuable insights on how to manipulate them for anthropogenic purposes. Lund Nano Lab has been important for facilitating the production of microfluidic chips used in the experiments for the study of fungal hyphae at the micro scale at which their hyphae operate.

Hanbang Zou

USER CASE: RECONFIGURABLE NANOWIRE TRANSISTORS

Motivated by the promise of extending Moore's Law through increased functional density, reconfigurable transistors have interested both academia and industry. This work presents a novel reconfigurable device technology based on nanowire ferroelectric tunnel field-effect transistors (ferro-TFETs). The key fabrication step involves growing high-quality hafnium zirconium oxide (HZO) on the nanowire TFETs using atomic layer deposition (ALD). This is followed by an annealing step at 450°C to induce ferroelectricity in the HZO layer which has spontaneous polarization controlled by an external gate voltage. This polarization persists even after the voltage is removed; a characteristic known as a non-volatile property. Depending on the polarization direction in the ferroelectric oxide, the threshold voltage of ferro-TFETs can be shifted, providing the device reconfigurability. The entire processing has been conducted in Lund Nano Lab where we have established reliable vertical fabrication schemes for various nanoelectronic devices thanks to its advanced facilities and meticulous maintenance.

Zhongyunshen Zhu

STRATEGIC COLLABORATION WITH THE OLLE ENGKVIST FOUNDATION: 100 MSEK FOR NANOLAB SCIENCE VILLAGE

During 2023, NanoLund established a long-term strategic collaboration with the Olle Engkvist Foundation, who intends to support the purchase of equipment for Nanolab Science Village to the tune of SEK 100 million over five years.

Through this collaboration, the foundation wishes to support the very strong, leading interdisciplinary research environment that is to be found at NanoLund. Nanotechnology holds the key to revolutionary solutions for the planet and humanity's best. As such, the foundation views the strategic collaboration around the establishment of a new laboratory in Lund's new neighbourhood, Science Village, as very satisfying.

"My researcher colleagues and I are very grateful for the support from the Olle Engkvist Foundation. When we are 'crafting' at an atomic level, in order to create better conditions for both humanity and the planet, an optimally-equipped laboratory and the proximity to the two major research facilities – MAX IV and ESS – provide unique possibilities," says Maria Messing, deputy director of NanoLund.

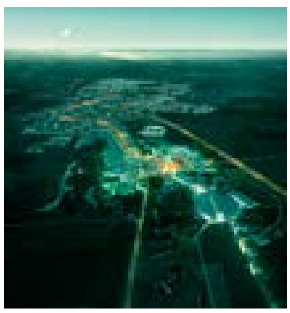


Illustration: COBE

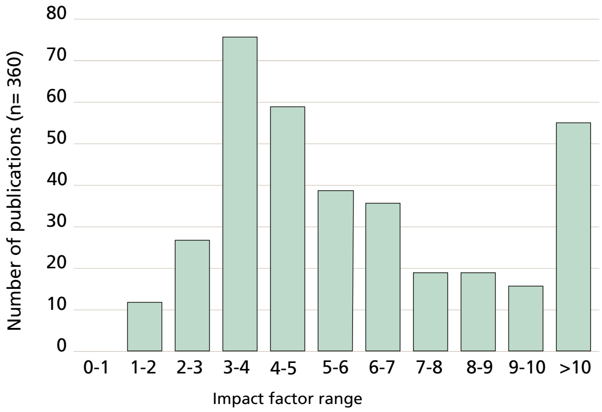
Scientific publications

Our most important way of communicating results and providing value to the scientific community is through high-quality scientific publications in widely cited peer-reviewed journals. In 2023, the number of publications from NanoLund was 462.

The quality of our publications remained high, with an average journal impact factor (JIF) of 6.98, averaged over all our publications relevant to nanoscience. 15 % of these publications were published in journals with a JIF larger than 10. The overall distribution of the JIF remains similarly shaped compared to the last years. We consider it a good sign that we have a balance between high-impact factor papers with high visibility and publications in archival journals peaking at an intermediate impact factor of around 3 to 4. This indicates a healthy mixture of specialised, in-depth research with visionary high-impact studies.

We see a continued increase in co-publications of our scientific results with both academic and industrial partners, as can be seen in the map below.

Journal impact factor distribution for NanoLund publications in 2023 (360 of the 373 nanoscience publications have a defined JIF)



PUBLICATIONS 2023

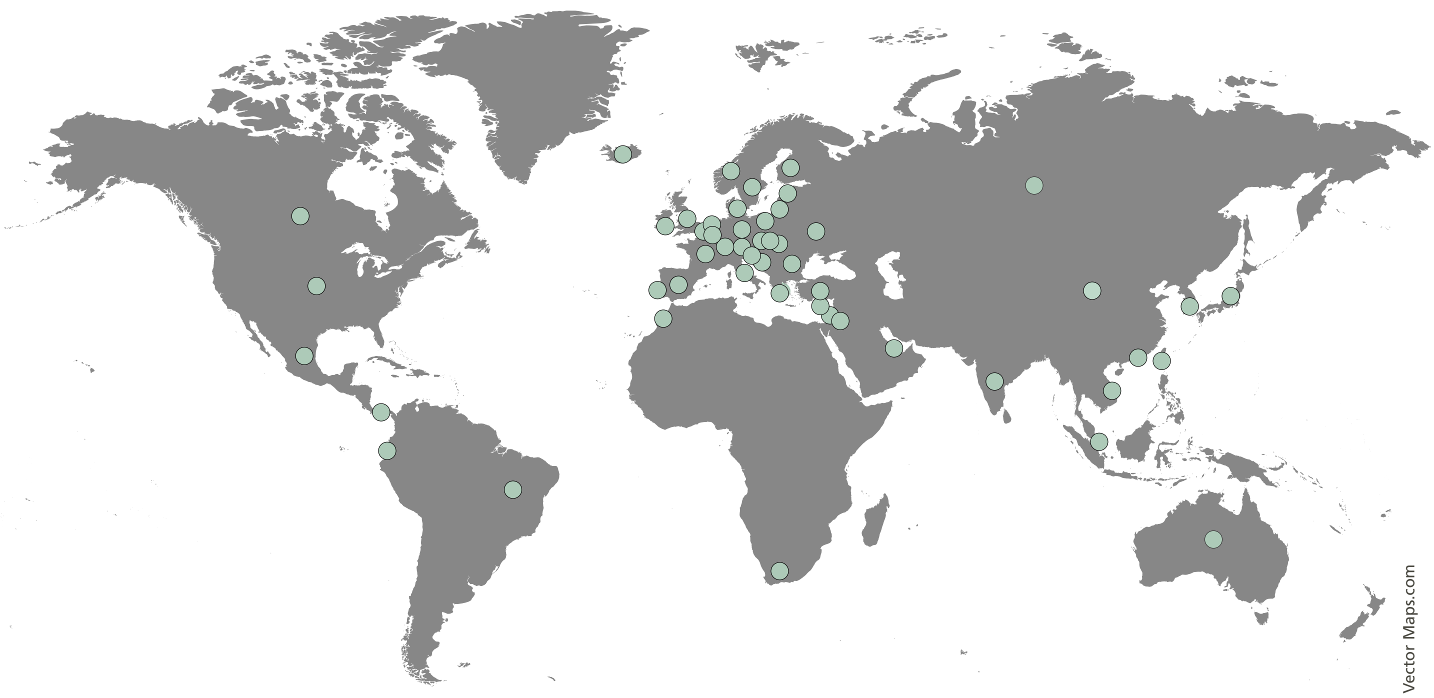
462 publications in total

373 publications directly related to nanoscience

56 nanoscience publications with journal impact factor > 10

6.98 average journal impact factor

477 co-publishing international institutions



In 2023 NanoLund researchers co-published with researchers at 477 international institutions in 51 different countries and with 16 Swedish universities and 41 companies world-wide.

NanoLund Awards

NANOLUND AWARD FOR EXCELLENT TECHNICAL AND ADMINISTRATIVE SUPPORT

The outstanding work done by our technical and administrative staff is of critical importance for NanoLund and without this none of our research and teaching would be possible. The award for excellent technical and administrative support recognises special achievements of technical and administrative personnel.

Gerda Rentschler, Project coordinator, Solid State Physics
Noomi Egan, Communications officer, Cooperation office

NANOLUND YOUNG TEACHER AWARD

The efforts of junior staff are often crucial for the courses we teach and help form the impression undergraduate students have of our research environment. The Young Teacher Award recognises the extraordinary commitment to teaching by junior scientists.

Mehran Sedrpooshan, PhD student, Synchrotron Radiation Research
Yue Zhao, PhD student, Solid State Physics

NANOLUND JUNIOR SCIENTIST IDEAS AWARD

The junior scientist ideas award is presented to the young researchers who are granted NanoLund seedling projects; proposals for novel research projects submitted by master's students, PhD students and postdocs at NanoLund. The grantees are selected based on the originality, feasibility, potential impact and initiative of their proposed project from across all research areas of NanoLund. In 2023, 16 seedling project applications were received and evaluated by a group of senior scientists. Four projects were selected for funding by a sum of SEK 100 000 per project.

Elham Akbari, Solid State Physics – *Tissue-in-a-pit an infection-on-a-chip, microfluidic system to mimic host-pathogen Interactions.*
Ivan Unksov, Solid State Physics – *Biosensor for DNA based on fluorescent silver nanoclusters, semiconductor nanowires, and DNA origami.*
Mehran Sedrpooshan, Synchrotron Radiation Research – *Novel Surface Coating Technique via Spark-Ablation*.
Patrik Olausson, Nano Electronics – *Vertical MOSFETs using a "semiconductor-last" approach based on Template-Assisted Selective Epitaxy.*

NANOLUND DISTINCTION FOR PHD STUDENTS

NanoLund Distinction is awarded to a PhD student graduating within the NanoLund environment who has shown particular dedication to research, education and outreach activities, who has acquired a broad knowledge of nanoscience research and its societal relevance and impact and who has demonstrated research independence and leadership beyond what is in general required for a PhD degree in Sweden.

Jonatan Fast, Solid State Physics
Klara Suchan, Chemical Physics
Pradheeba Surendiran, Solid State Physics
Sandra Benter, Synchrotron Radiation Research

Photo: Evelina Lindén

The coming generation of nano-scientists

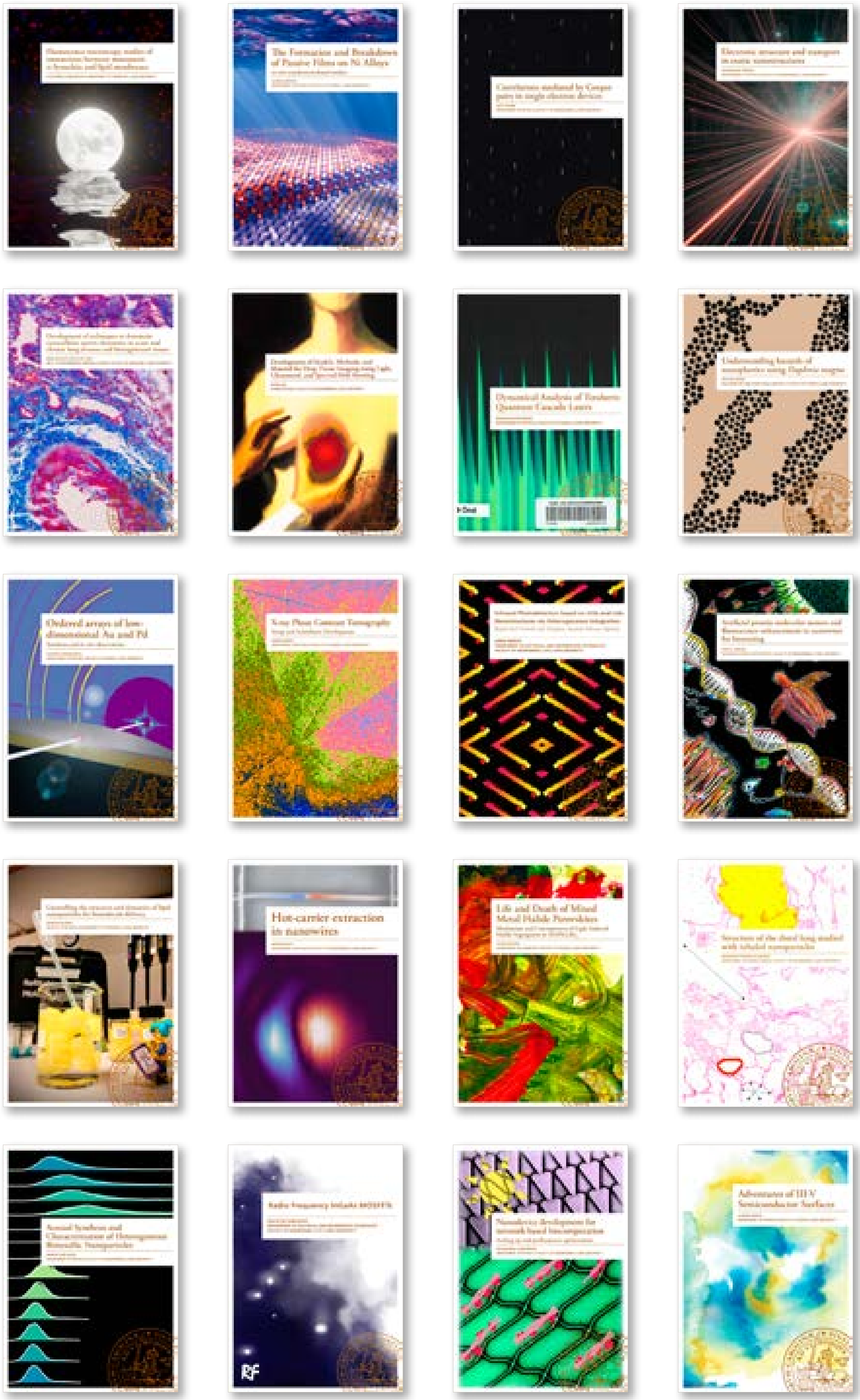
NanoLund is Sweden's largest research environment for interdisciplinary nanoscience and nanotechnology. In 2023, we engaged about 160 PhD students in sciences ranging from engineering to natural sciences and medicine. Currently, there are four industrial PhD students enrolled within NanoLund. The PhD students constitute roughly one-third of the staff engaged in NanoLund and are an important and integrated part of our research environment.

In the table below NanoLund PhD students who defended their theses are listed. We wish everyone the best for their future careers.

NANOLUND PHD THESES DEFENDED DURING 2023

More information can be found on our web page, nano.lu.se/previous-phd-theses

Alexandra Andersson	Physical Chemistry	*Fluorescence microscopy studies of interactions between monomeric α-Synuclein and lipid membranes*
Alfred Larsson	Synchrotron Radiation Research	*The Formation and Breakdown of Passive Film on Ni Alloys: in situ synchrotron studies*
Antti Ranni	Solid State Physics	*Correlations mediated by Cooper pairs in single-electron devices*
Athanasios Tsintzis	Solid State Physics	*Electronic structure and transport in exotic nanostructures*
David Hill	Atomic Physics	*Development of Models, Methods, and Materiel for Deep Tissue Imaging using Light, Ultrasound, and Spectral-Hole Burning*
Denizhan Ekin Önder	Mathematical Physics	*Dynamical Analysis of Terahertz Quantum Cascade Lasers*
Egle Kelpsiene	Biochemistry and Structural Biology	*Understanding hazards of nanoplastics using Daphnia magna*
Giuseppe Abbondanza	Synchrotron Radiation Research	*Ordered arrays of low-dimensional Au and Pd*
Hani Alsafadi	Lung Bioengineering and Regeneration	*Role of the co-transcriptional regulators Yap/Taz in the normal and fibrotic lung epithelia*
Hanna Dierks	Synchrotron Radiation Research	*X-ray Phase Contrast Tomography: Setup and Scintillator Development*
Heera Menon	Nano Electronics	*Infrared Photodetectors based on InSb and InAs Nanostructures via Heterogeneous Integration-Rapid Melt Growth and Template Assisted Selective Epitaxy*
Iran Augusto Silva	Lung Bioengineering and Regeneration	*Development of techniques to determine extracellular matrix alterations in acute and chronic lung diseases and bioengineered tissues*
Ivan Unksov	Solid State Physics	*Artificial protein molecular motors and fluorescence enhancement in nanowires for biosensing*
Jennifer Gilbert	Physical Chemistry	*Unravelling the structure and dynamics of lipid nanoparticles for biomolecule delivery*
Jonatan Fast	Solid State Physics	*Hot-carrier extraction in nanowires*
Klara Suchan	Chemical Physics	*Life and Death of Mixed Metal Halide Perovskites: Mechanism and Consequences of Light Induced Halide Segregation in MAPb(I,Br)3*
Linnea Lindh	Chemical Physics	*Photophysics and Photochemistry of Iron Carbene Complexes*
Madeleine Petersson Sjögren	Ergonomics and Aerosol Technology	*Structure of the distal lung studied with inhaled nanoparticles*
Mahdi Rezayati Charan	Biomedical Engineering	*Characterization and Separation of Suspension Cells by Isoacoustic Focusing*
Marcel Sayre	Functional Zoology	*Neural correlates of diverse navigational strategies*
Markus Snellman	Solid State Physics	*Aerosol Synthesis and Characterization of Heterogeneous Bimetallic Nanoparticles*
Navya Sri Garigapati	Nano Electronics	*Radio Frequency InGaAs MOSFETs*
Oskar Ström	Solid State Physics	*Microfluidic Preparation and Transport of Long DNA using Pillar Arrays*
Pradheebha Surendiran	Solid State Physics	*Nanodevice development for network-based biocomputation: Scaling up and performance optimization*
Robin Sjökvist	Centre for Analysis and Synthesis	*In-situ Study of the Growth, Composition and Morphology of III-V Semiconductor Nanowires*
Sandra Benter	Synchrotron Radiation Research	*Adventures of III-V Semiconductor Surfaces*
Sara Franzén	Solid State Physics	*Design and development of solid-state nanostructures for catalysis*
Susanna Hammarberg	Synchrotron Radiation Research	*Strain Mapping of Single Nanowires using Nano X-ray Diffraction*
Victoria Ptasinski	Lung Bioengineering and Regeneration	*Alveolar Progenitor Cells in Lung Damage and Regeneration in Pulmonary Fibrosis*



A selection of cover pages from NanoLund theses 2023.

How we are organised

NanoLund is headed by a board, which defines strategy and makes formal decisions. The centre is advised by an international scientific advisory board and an external advisory council with members from society, academia and industry. Our research is organised into research areas and we have three resource areas that enable and complement the scientific work.

HISTORY

2022 Launch of LTH profile area Nanoscience and Semiconductor Technology

Launch of LU profile area Light and Material

2020 New strategic plan

2016 NanoLund forms a vision and starts strategic work for establishment at Science Village

2015 The strategic research area becomes NanoLund, the Centre for Nanoscience at Lund University

2009 Strategic research area selected by the Swedish Government

2007 Inauguration of Lund Nano Lab

2003 Starting the new education program Engineering Nanoscience (BSc and MSc)

1995 SSF funds nmC with several significant grants until 2012

1988 The Nanometer Structure Consortium (nmC) is initiated

BOARD

Heiner Linke (Chair), *Deputy Dean, Faculty of Engineering* | **Elizabeth Blackburn,** *Faculty of Science* | **Erik Lind,** *Faculty of Engineering* | **Kerstin Jakobsson,** *CEO Kongsberg Beam Technology AS* | **Kimberly Dick Thelander,** *Faculty of Engineering* | **Kristian Pietras,** *Faculty of Medicine* | **Mats Qvarford,** *Strategic Partnership Manager, Tetra Pak* | **Peter Honeth,** *Former State Secretary, Sweden* | **Tönu Pullerits,** *Faculty of Science* | **Patrik Nilsson,** *student representative* | **Simon Wozny,** *student representative* | **Marcus Lindén,** *student representative*

MANAGEMENT GROUP

Anders Mikkelsen, *Director* | **Maria Messing,** *Deputy Director* | **Anneli Löfgren,** *Co-Director* | **Christelle Prinz** | **Ivan Scheblykin** | **Martin Leijnse** | **Tommy Nylander**

SCIENTIFIC ADVISORY BOARD

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EXTERNAL ADVISORY COUNCIL

Anna Hall, *AlfaLaval* | **Anna Stenstam,** *CR Competence* | **Daniel Kronmann,** *Region Skåne* | **Ebba Fåhraeus,** *SmiLe Incubator* | **Jan-Eric Sundgren,** *Independent consultant* | **Lars Börjesson,** *Chalmers University* | **Madelene Sandström,** *the Royal Swedish Academy of Engineering Sciences (IVA)*

COORDINATORS' FORUM

The coordinators' forum is made up of the coordinators for the NanoLund research and resource areas, the members of the management group, the chair of the board and the student representatives of the board.

NANOLUND SCIENTIFIC ADVISORY BOARD


Andrew N. Jordan


Chris Palmstrøm


Heike Riel


Iseult Lynch


Martin Wolf


Patricia Bassereau


Robert Feidenhans'l

How we have developed

During 2023, 425 persons were involved in NanoLund as principal investigator (PI), researcher, PhD student or technical and administrative staff. The majority is distributed over three faculties at Lund University and MAX IV, and about 5% of NanoLund staff is affiliated with institutions other than Lund University. Of the PIs, the number of Faculty Members and Affiliated Faculty Members were 59 and 55, respectively.

In the past years, we have seen an increased interest in collaborating and becoming a part of our research environment. Since NanoLund became a strategic research area in 2009, the number of postdocs and PhD students has tripled. In contrast, the number of PIs (Faculty and Affiliated Faculty Members) have remained approximately constant, an indication that the NanoLund research groups are thriving. This is also shown by the increasing external funding, i.e. research grants won in competitive calls. The number of publications keeps increasing.

Gender balance

NanoLund strives for gender balance and for being a diverse and inclusive workplace. Overall, 35% of the total staff at NanoLund are women.

The proportion of women among Faculty and Affiliated Faculty Members has increased also this year. We will continue taking actions to keep improving the gender balance at all levels over the following years as we work with faculties and departments on even better and more diverse recruitment.

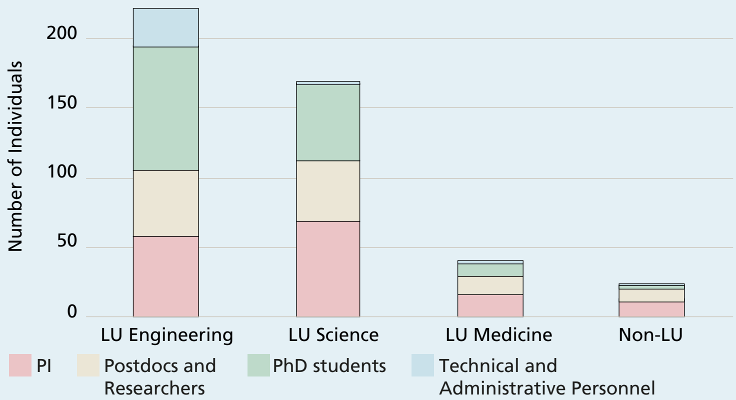
GENDER STATISTICS FOR ACADEMIC POSITIONS IN 2023

PI:s
25% women | 75% men

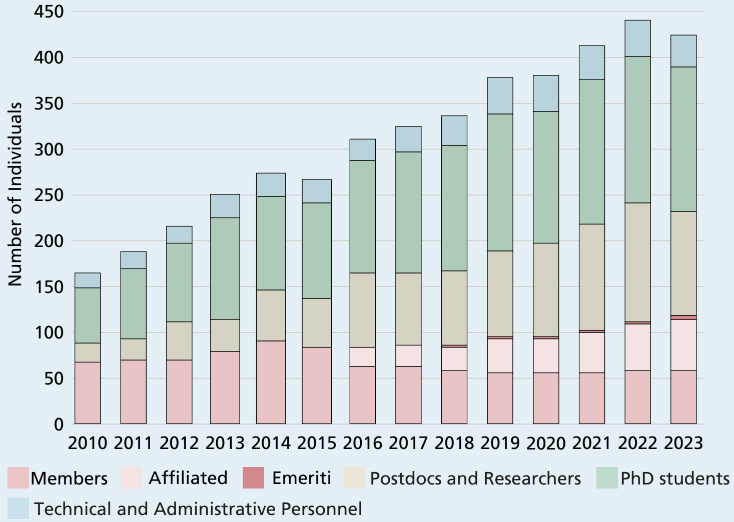
Postdocs and Researchers
36% women | 64% men

PhD students
39% women | 61% men

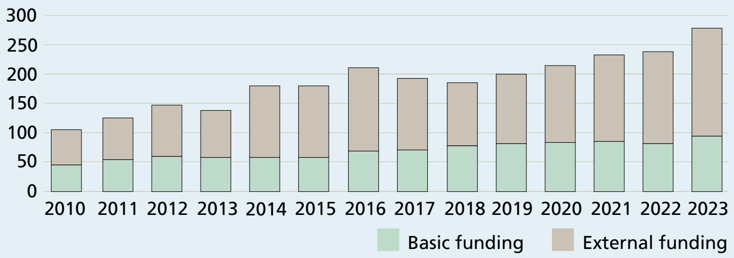
NanoLund people by faculty



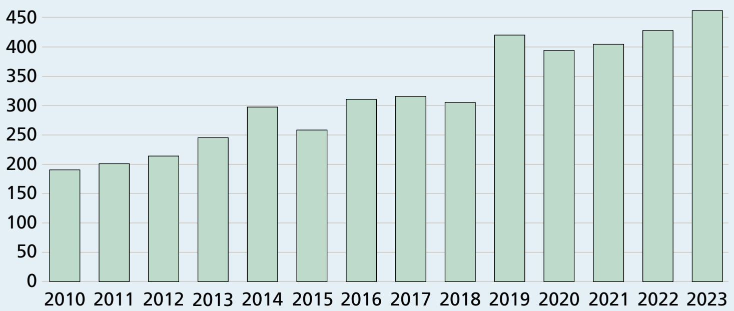
Personnel trends 2010–2023



Funding over time (MSEK)



Total number of publications over time



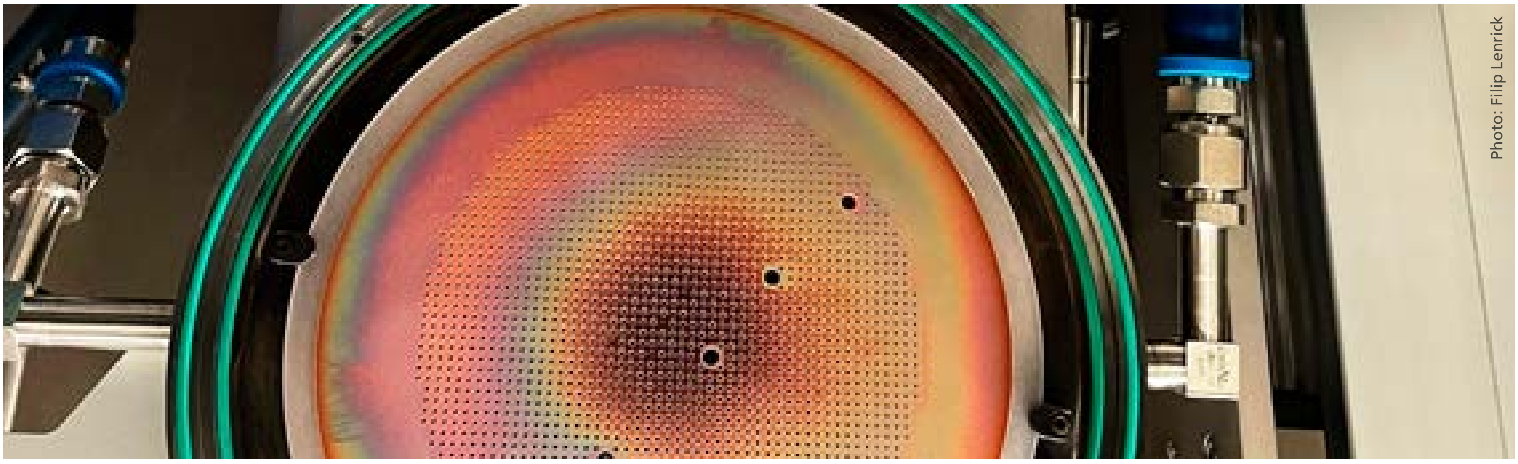


Photo: Filip Lenrick

Funding

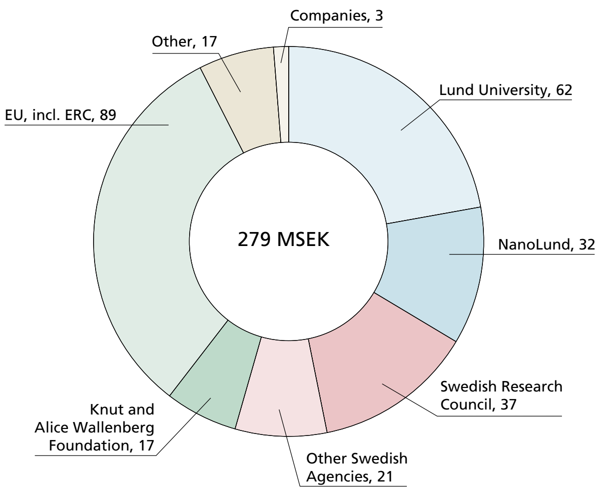
NANOLUND INCOME SOURCES

Funding for NanoLund and our researchers comes from a range of national and international funding agencies. This combination ensures that our interdisciplinary environment has the necessary resources to conduct nanoscience research at the highest international standard.

The total income is assessed as direct funds to NanoLund and our faculty members' income, weighted by their degree of engagement in NanoLund.

In 2023 the total income for NanoLund was SEK 279 million. SEK 185 million, corresponding to 66 % of the total income, was external funding won in competitive calls. This is an increase of SEK 40 million compared to 2022 and is mainly due to an increase in the amount of funding from the European Research Council. In 2023 NanoLundians were awarded and started new ERC-grants and many on-going projects had periodic reporting with subsequent intermediate payment during the year. SEK 94 million came from Lund University, of these SEK 32 million are strategic research area funding for NanoLund. See the diagram below for the distribution of funding from individual income sources the past year.

NanoLund income sources 2023 (MSEK)



FUNDING HIGHLIGHTS

NanoLundians are active and successful in applying for externally funded grants, and many hold highly prestigious grants. In 2023, NanoLund grantees included:

- 16 active European Research Council (ERC) grants (in total 21 NanoLundians have received ERC-grants since the start of the strategic research area)
- Participation in 17 EU-projects
- Coordination of 3 of our 17 EU-projects
- 4 Wallenberg Scholars or Fellows
- 3 Knut and Alice Wallenberg (KAW) project grants
- 1 Novo Nordisk Foundation Excellent Research Leader
- 3 Swedish Research Council Distinguished Professors
- 3 Swedish Research Council Research Environments
- 2 Future Research Leaders from the Swedish Foundation for Strategic Research, SSF
- 1 Strategic Mobility Grant from SSF
- 3 Vinnova Competence centres within Sustainable industry and Digital transformation
- 18 approved research projects, consolidator and starting grants from the Swedish Research Council

> "Our funders are invaluable to us, as they make it possible for us to conduct cutting-edge research with state-of-the-art equipment."

Anders Mikkelsen, director of NanoLund

Thanks to our funders

AFA Insurance
Alfred Österlunds Siftelse
Business Region Skåne AB
Cancerfonden
Carl Tryggers stiftelse för vetenskaplig forskning
The Crafoord Foundation
Danish Offshore Technology Centre
Ericsson AB
European Commission's Research and Innovation Activities: European Research Council (ERC), Marie Skłodowska-Curie Actions, Horizon 2020 and FP7
FORMAS – Swedish Research Council for Sustainable Development
Forte, the Swedish Research Council for Health, Working Life and Welfare
FQXi (Foundational Questions Institute)
Hjärnfonden – the Swedish Brain Foundation
The Independent Research Fund Denmark
The Kamprad Family Foundation for Entrepreneurship, Research & Charity
The Knut and Alice Wallenberg Foundation
LMK Foundation for Interdisciplinary Scientific Research
Magn. Bergvalls Stiftelse
The Mats Paulssons Stiftelse för forskning, innovation och samhällsbyggande
MISTRA, the Swedish Foundation for Strategic Environmental Research
The Novo Nordisk Foundation
The Office of Naval Research
Olle Engkvists stiftelse
Region Skåne
The Royal Physiographic Society of Lund
Saab AB
Seco Tools AB
Sida – Swedish International Development Cooperation Agency
Sparbanksstiftelsen Finn
Stiftelsen Kronprinsessan Margaretas Arbetsnämnd för synskadade (KMA)
Stiftelsen Seydlitz MP bolagen
Stiftelsen Sigurd & Elsa Goljes Minne
STINT – The Swedish Foundation for International cooperation in Research and Higher Education
The Swedish Agency for Economic and Regional Growth
The Swedish Alzheimer's Foundation
The Swedish Energy Agency
The Swedish Foundation for Strategic Research, SSF
The Swedish Heart-Lung Foundation
The Swedish Research Council
Swedish Water Research
TetraPak
United Monolithic Semiconductors
Veeco SiC CVD Systems AB
Vinnova – Sweden's innovation agency
Volvo Cars
Åforsk

Photo: Evelina Lindén

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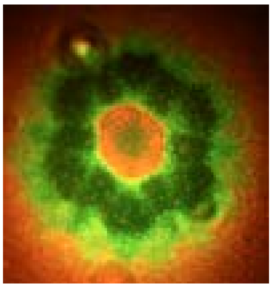
The NanoLund Annual Report 2023 presents highlights, progress, data, statistics and trends for the research environment in 2023.

This report is based on material and data compiled and edited by the staff of NanoLund, in particular: **Evelina Lindén,** Communication | **Mirja Carlsson Möller,** Centre Coordinator | **Anna-Karin Alm,** External Relations Officer | **Gerda Rentschler,** Project Coordinator | **Anneli Löfgren,** Administrative Director | **Anders Mikkelsen,** Director | **Maria Messing,** Deputy Director | **Anne Nielsen,** Centre Coordinator

To order a paper version of the NanoLund Annual Report 2023, please contact **info@nano.lu.se**

On the cover: PhD student Julia Valderas Gutiérrez participated in the NanoLund image competition with this nano-flower: "Cell membranes are complex fluid systems composed of mobile lipids that play a crucial role in cell's survival. Model membranes can be formed and studied on vertical arrays of light guiding silicon nanowires adding lipid vesicles that fuse together when a critical concentration is reached. Using epifluorescence microscopy, we see a wave effect suddenly "engulfing" the nanowires, and the lipids, whose fluorescence is enhanced by the nanowires, diffuse laterally within the membrane. A fluid membrane also flows around this flower-like beautiful defect of the nanowire platform, using three different dyes."



LUND UNIVERSITY

NanoLund
CENTRE FOR NANOSCIENCE

LUND UNIVERSITY

NanoLund
Box 118
SE-221 00 Lund

www.nano.lu.se