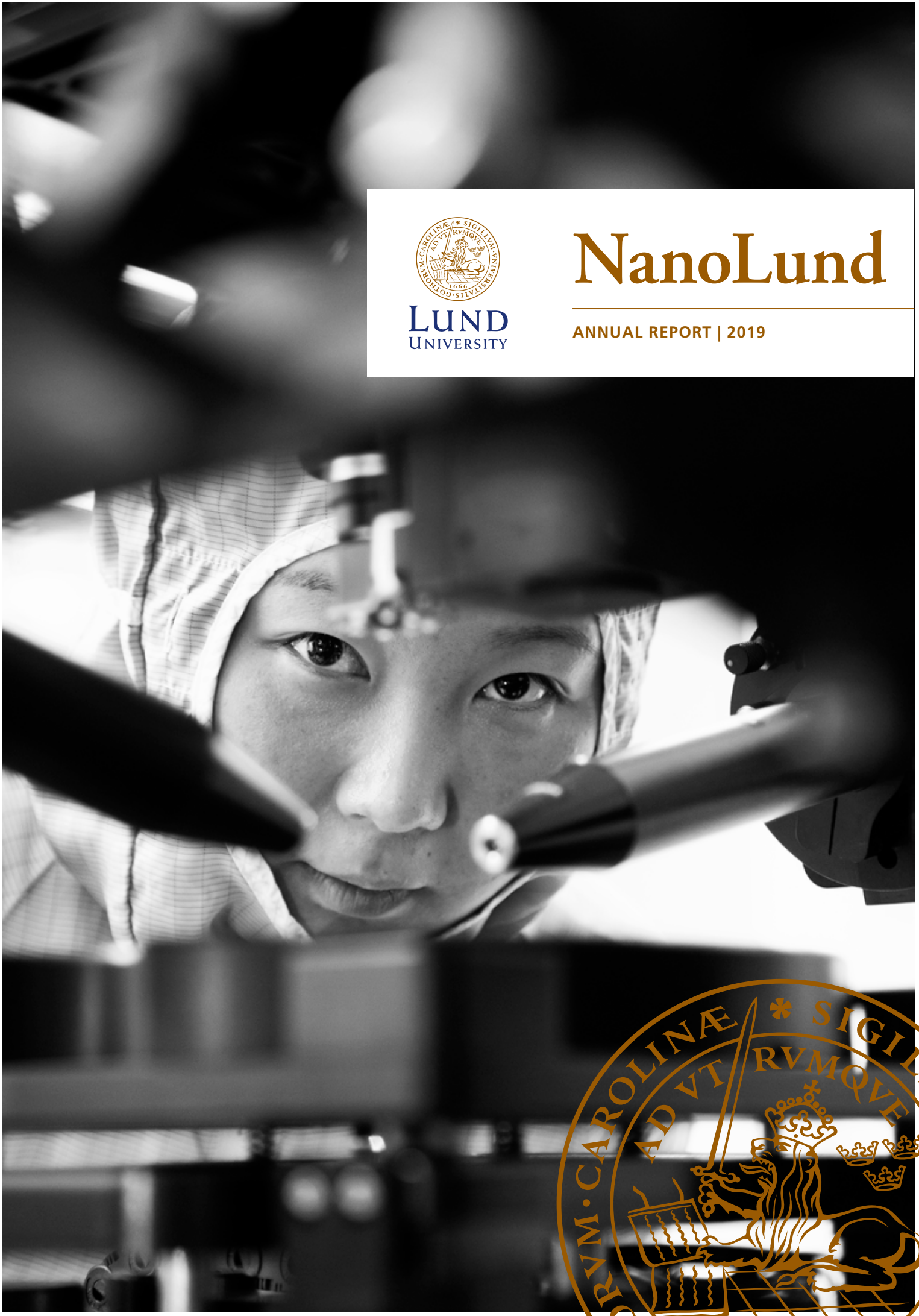


LUND UNIVERSITY

NanoLund

ANNUAL REPORT | 2019

A center has many roles

LONGTERM STABILITY ENABLES US TO DELIVER ON HIGH EXPECTATIONS

The past year marks the 10th anniversary of continuous, direct support by the Swedish government to NanoLund as one of its Strategic Research Areas. This extraordinary status entails a longterm, mutual agreement: for NanoLund to live up to very high standards, and for the university and government to provide the longterm stability that is indispensable for our ability to fulfill these high expectations. We are committed to:

- performing excellent basic and applied research at the international forefront;
- engaging in education at all levels;
- building and running infrastructure used by academia, institutes and industry;
- recruiting top-level international students and scientists, and helping to enhance diversity with respect to gender and background;
- addressing societal challenges in open collaboration with external partners regionally, nationally and internationally;
- pursuing well-defined strategic aims by leveraging substantial external support;
- training the next generations of academic leaders;
- providing high visibility to our scientists and the University.

We do indeed deliver on all of these aspects. Highlighting scientific excellence, 2019 brought a new record-high of 286 publications related to nanoscience and nanotechnology, in journals with an average impact factor of as high as 6.0. Our members attracted prestigious European and Swedish grants, including two new ERC grants, three Research Environments awarded by the Swedish Research Council, and three Wallenberg Scholar awards. There are now 15 spin-out companies in operation, and last September we kicked off our new stakeholder network, NanoTechNow. The planning of NanoLab Science Village, a user facility for universities, industry, MAX IV and ESS, is moving into the next phase.

I am very proud of the strong engagement of our members and staff that enables this breadth of high-level activity. Together we engage in more than 25 leadership and coordination roles within the Center organization. None of what we do would be realized without the extraordinary skill and pioneering contributions of our excellent administrative staff, technical personnel, students and postdocs.

I am most grateful also to all our external partners in academia, industry, institutes, local and national administration, who support us with insights, cooperation, and advice, often behind the scenes. Your help and cooperation are invaluable to us. Thank you!

Photo: Mikael Risedal

Heiner Linke, Director

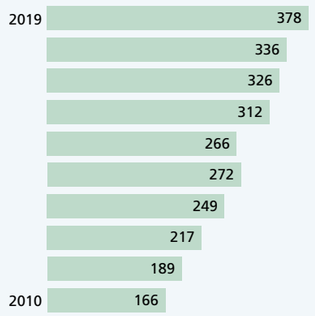
Photo: Charlotte Carlberg Bärg

2019 in brief

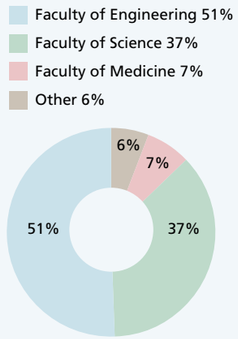
IN 2019, NANOLUND

- Included 11 faculty members who are ERC awardees
- Participated in 12 EU-projects
- Coordinated 2 EU-projects
- Included awardees of 2 Marie Skłodowska-Curie Individual Fellowships

STAFF

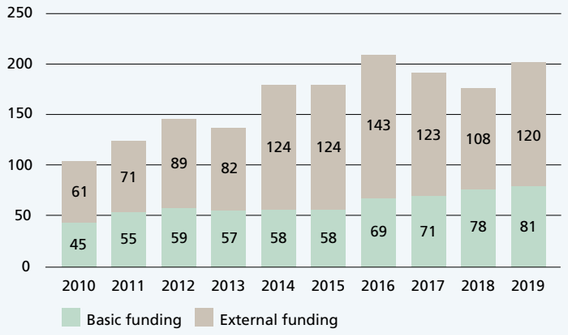


FACULTY AFFILIATION

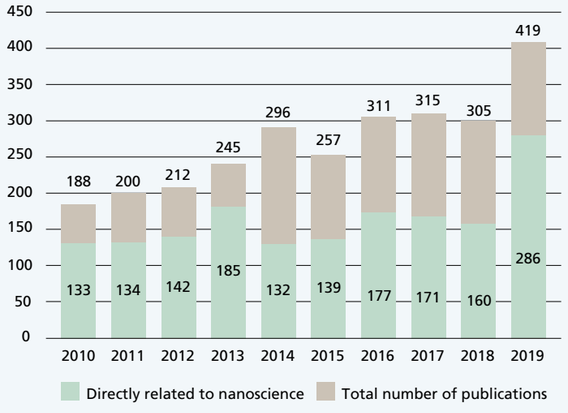


TRENDS

Funding over time (MSEK)



Total number of publications



CURRENT NUMBERS

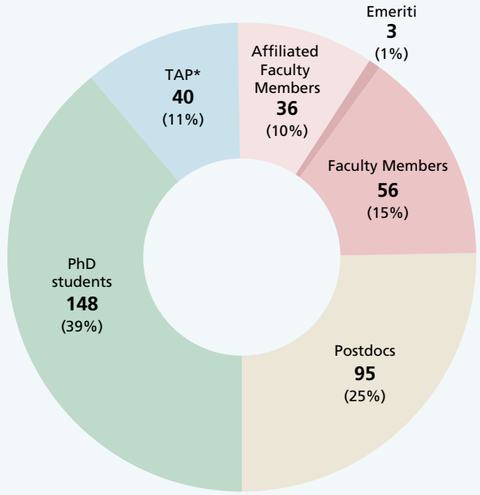
MSEK funding 59% external	201
Average impact factor	6.0
Contributing LU divisions	23
Faculty Members	56
Women %	36
PhD students	148
Undergraduate student members	>150

HISTORY

There are now 15 active spin-off companies that have emerged from the NanoLund environment	2019
The Strategic Research Area becomes NanoLund, the Center for Nanoscience at Lund University	2015
Strategic Research Area funded by the Swedish Government	2010
Inauguration of Lund Nano Lab	2007
Starting the new education program Engineering Nanoscience (BSc and MSc)	2003
SSF funds nmC with several major grants until 2012	1995
The Nanometer Structure Consortium (nmC) is initiated	1988

People

People per personnel category 2019



PERSONNEL & MEMBERSHIP

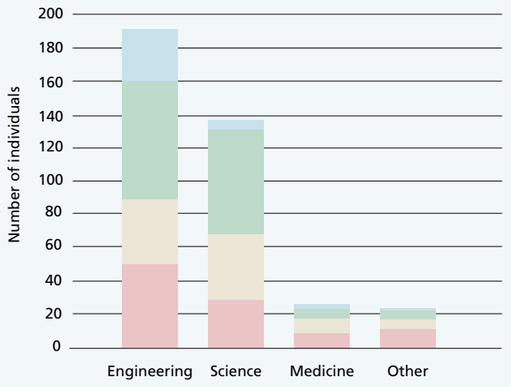
Since NanoLund became a Strategic Research Area in 2009, the number of postdocs and PhD students has tripled, whereas the number of Faculty Members (research group leaders) has remained approximately constant. The average annual level of engagement in NanoLund overall is 63%, which corresponds to 241 full-time equivalents. In the past year we have seen an increase in the number of PIs who become Affiliated Faculty Members, indicating an increased interest in collaborating and becoming a part of the research environment.

Gender Balance 2019

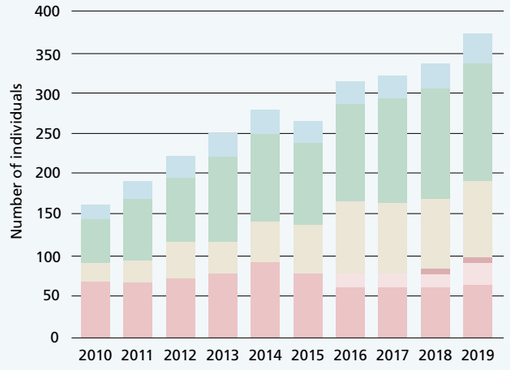
NanoLund strives for gender balance and being a diverse and inclusive workplace. Current stats are:

PIs:	24% women	76% men
Postdocs:	25% women	75% men
PhD students:	45% women	55% men

NanoLund people by faculty, 2019



Personnel trends 2010–2019



LEGEND
(Applies to all figures on this page)

- PhD students
- Postdocs
- TAP

Principial investigators:

- Faculty Members
- Affiliated Faculty Members
- Emeriti

* TAP = Technical and Administrative Personnel

The seven research areas of NanoLund – experiment and theory, side by side

MATERIALS SCIENCE

Materials science relates the atomic structure to the properties of a material. It also governs when and how nanostructures grow, and what structure to expect. Even very small changes in growth conditions can cause dramatic changes in the resulting nanostructure, and the challenge is to detect and control these – in real time!

Material science research, and the ability to create designed nanostructures, forms a basis of all research areas within NanoLund. Our key expertise is in solid-phase nanostructures fabricated from the vapor phase, especially metal nanoparticles and semiconductor nanowires. To ensure development of high-quality nanostructures, experiment is combined with theory and simulations to warrant a fundamental understanding of the material formation process. We use advanced techniques to characterise the nanostructures, and continuously develop new processes and applications.

QUANTUM PHYSICS

In nanostructured systems, pronounced quantum behavior can be observed that gives rise to exciting new fundamental physics as well as potential applications. We develop the theoretical tools to better describe such quantum phenomena, work to experimentally observe them, and then to identify advanced device concepts where quantum effects enable better performance.

Examples of such quantum resources include the superposition of states and entanglement, which open completely new perspectives for communication technology. We employ quantum thermodynamics to develop 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. We also study the interaction of light with nanostructured materials, in order to improve e.g. the in- and out-coupling of light into nanostructures which is of importance for electro-optical devices.

NANOENERGY

The need for clean and sustainable energy is one of our greatest global challenges. We aim to harness the unique electronic, photonic and structural properties of highly controlled nanomaterials to harvest and convert energy with higher efficiency and with less material use than currently possible.

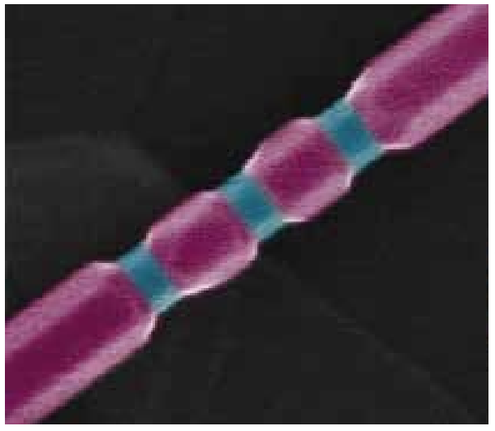


Photo: Sebastian Lehmann & David Barker

SEM image of an InAs nanowire with GaSb shell grown preferentially on zinc blende InAs.

Harvesting solar energy is one topic. If we could convert a small fraction of the solar energy to useful energy forms, our future energy supply would be secured. Our research interests include multi-bandgap devices with high efficiency, as well as molecular and hybrid systems. Other application areas are efficient displays and electrical vehicles.

At the nanoscale, electrons and atoms perform random thermal motion and can be subject to quantum effects. Can we use the kinetic energy of electrons to do useful work? Can quantum phenomena make energy conversion more efficient? We combine experiment and theory to explore the fundamentals of power generation using heat and light, as well as information.

NANOELECTRONICS AND PHOTONICS

Electronic and photonic devices are at the heart of the modern information society. We aim to use advanced, controlled nanostructures to demonstrate novel devices as well as to improve and refine conventional devices – one focus is on nanowires.

High performance electronics are designed and implemented on the nanoscale. Smaller device geometries lead to higher operation frequencies, larger signal gain and better packing density. We explore transistors close to the atomistic limit to implement high performance electronics devices for radio frequency (RF) and computation.

At the nanoscale, light interacts with matter in novel ways. There are many ways to affect the way light and matter interacts by designing suitable nanostructures. We investigate both how to understand the nanostructures on a quantum level as well as how to control light using nanostructures. Is it possible to improve optical devices using nanostructures? Can we use light to "see" exactly what nanostructures look like?

NEURONANOSCIENCE AND NANOBIOLOGY

Our general aim is to develop nanoscale tools to unravel fundamental mechanisms that take place at the nanoscale in biological cells, and to make use of biological mechanisms for applications ranging from diagnostic to alternative computing.

By manipulating and controlling molecules and cells on their natural length scales, we develop novel tools to address urgent needs in biology and medicine for DNA analysis, cell fractionation and cell manipulation on the single-cell level.

We strive for a detailed understanding of the interactions between cells and nanostructures with respect to cell behavior, cell physiology and cell mechanics. This knowledge will allow us to develop novel nanoscale devices with applications in biology and medicine, such as the development of nanowire devices that can interact with cells with minimal cell perturbation, and controlling the cell behavior.

Another objective is to unravel fundamental dynamic neural and glial mechanisms in order to understand how learning and information processing works. Specifically, we develop implantable and biocompatible nanostructured neural interfaces that will allow us to study neurocommunication in conscious individuals.

NANOSAFETY

Nanoparticles have new properties that often are not present at the macroscale. It is therefore crucial to increase our understanding of the fundamental connections between nanoparticles and human and environmental toxicology, as well as of emissions and exposure in all stages of the lifecycle of a nanomaterial. Our research aims at providing the tools needed to implement Safe(r)-by-design in the development and production of novel materials. To generate the knowledge needed, we assess "real world" emissions and exposure in all stages of the life cycle of a nanomaterial as well as properties of emitted particles using state-of-the-art on-line and off-line methods.

The toxicological effects on cellular, organism and ecosystem are studied on all levels, from single cells to ecosystems using various in-vitro, ex-vivo, and in-vivo methods. We also study trophic transfer of nanomaterials, as well as the toxic effects thereof, using model ecosystems and mesocosm systems.

Safe production and use of nanomaterials require effective risk management. We combine knowledge of nano-related exposure and toxicity with state-of-the-art processes and procedures for risk management, ranging from legislative and regulative levels down to hands-on work processes.

EXPLORATORY NANOTECHNOLOGY

This is the testing ground for innovative nanotechnology concepts, aiming to evaluate their strategic importance for NanoLund. We explore novel methods to fabricate nanostructures and devices with atom-level control. We investigate possible ways to combine heterogeneous materials and devices in 3D, and we explore novel material properties that emerge due to the nanostructuring and long-range order of materials.

Good control over the interfaces of nanodevices ensures control over the electrical, optical and other properties of the devices. The combination of materials and devices that traditionally do not go together can open a wide range of scientific and technical opportunities. We explore new processes and technology to combine advanced materials of high quality that can enable new physics and breakthroughs in system performance. We focus specifically on methods to integrate distinct materials and functionality on top of each other (3D) without degradation of underlying structures.

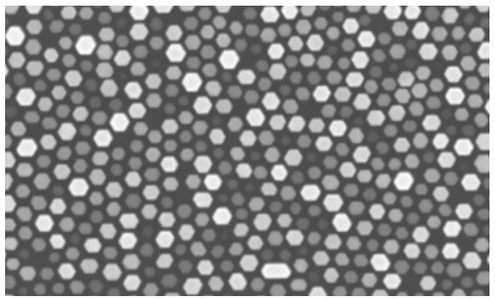


Photo: Anette Löfstrand

Scanning Electron Microscopy top view of InAs vertical nanowires grown on a InAs/Si substrate by a selective area epitaxy with SiNx as a mask.

News 2019

NEW SPIN-OUTS: ALIXLABS AND ALIGND SYSTEMS

NanoLund spawned two new spin-off companies in 2019: AlixLabs, who develops methods with the potential to reduce production costs in the semiconductor industry, and AligND Systems, who develops low-cost, nanowire-coated surfaces for use in diagnostic and bioanalytical devices with superior limit of detection, for example for use in cancer diagnostics. Both companies are based on inventions by NanoLund scientists and staff.

NANOPLASTICS FORMED DURING THE MECHANICAL BREAKDOWN OF DAILY-USE POLYSTYRENE PRODUCTSW

There is a considerable risk that plastic waste in the environment releases nano-sized particles known as microplastics, according to a new study from Lund University. NanoLund researchers studied what happened when plastic items such as takeaway coffee cup lids were subjected to mechanical breakdown, in an effort to mimic the degradation that happens to plastic in the ocean. The next step will be to further develop methods to track plastics in waste water and natural waterways.

M.T. Ekvall et al.Nanoscale Advances 1, 1055-1061 (2019)

https://doi.org/10.1039/c8na00210j

NANOLUND HOSTED MAJOR INTERNATIONAL CONFERENCE

In July, NanoLund organized the conference IVC-21 with a five-day program featuring two Nobel Laureates, eight plenary speakers, 350 oral contributions and 320 posters. NanoLundians gave three invited talks and 24 oral contributions.

Selected for Lindau Nobel Laureate Meeting

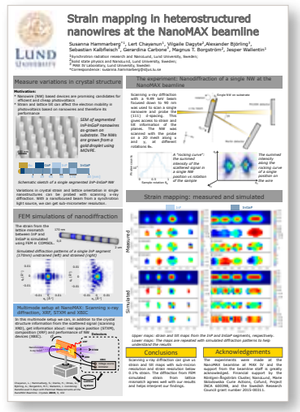
Rubén Seoane Souto and Yang Chen were two of 580 young scientists from 88 countries coming together with 42 Nobel Laureates in Lindau, Germany, in a meeting dedicated to physics; key topics were cosmology, laser physics and gravitational waves. Since 1951, the Lindau Nobel Laureate Meetings offer scientists numerous opportunities to inspire and network with one another. The young scientists selected for these meetings are outstanding undergraduates, PhD students and post-docs under the age of 35.

Photo: Julia Nimke/Lindau Nobel Laureate Meetings

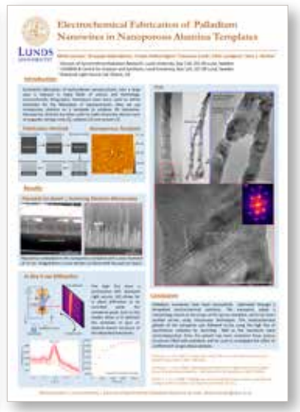
Selected outstanding young scientists meeting at Lindau, 2019.

BEST POSTER AWARDS FOR X-RAY DIFFRACTION AND ELECTROCHEMICAL FABRICATION

At the 31st MAX IV User Meeting in September, Susanna Hammarberg won the Student Poster Award 2019 for her poster "Strain mapping of nanowire device using scanning XRD". In December, Alfred Larsson won best poster award at the winter school "Conventional and High-energy spectroscopies for inorganic, organic and bimolecular surfaces and interfaces" in Florence, Italy for the poster "Electrochemical Fabrication of Palladium Nanowires in Nanoporous Alumina Templates".



Susanna Hammarberg



Alfred Larsson

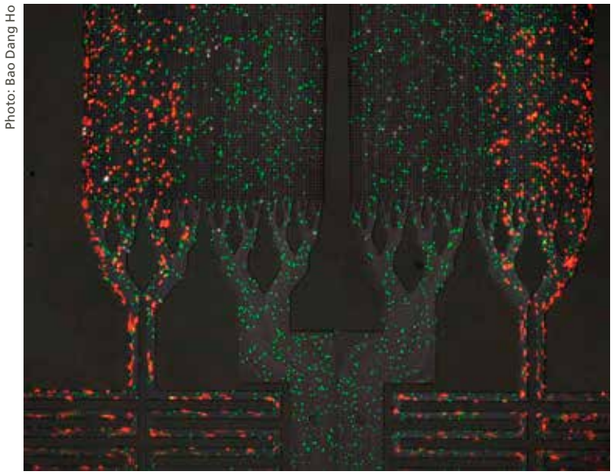


Photo: Bao Dang Ho

Purification of smalller microspheres (green) from a mixture of smaller and larger (red) microspheres.

Strong support from the Swedish Research Council for precision medicine

Our strategic emphasis on precision medicine – using nanotechnology tools for medical diagnostics – has received more than 80 MSEK in new grants from the Swedish Research Council. Thomas Laurell won a Distinguished Professor grant with the title "Ultrasonic standing wave fields and extracellular vesicles enable novel routes in medical diagnostics and biopharmaceutical production". Two teams including NanoLund scientists were awarded prestigious Research Environment Grants: "Multiscale biomechanics from molecules to cells in cancer" led by Jonas Tegenfeldt and with Chris Madsen, Pontus Nordenfelt and Vinay S. Swaminathan as co-applicants; "Single molecule bioanalytical sensing for precision cancer diagnostics" with Heiner Linke as PI and with Fredrik Höök, Christelle Prinz and Thoas Fioretis as co-applicants. In addition, NanoLund faculty member Sara Linse is a co-applicant for a third new Research Environment Grant, namely "CASCADE: Cause or Consequence in Alzheimer Disease?" led by Emma Sparr.

IN-SITU ANALYSIS OF CATALYST COMPOSITION DURING GOLD CATALYZED NANOWIRE GROWTH

Semiconductor nanowires offer the opportunity to incorporate novel structures and functionality into electronic and optoelectronic devices. For the first time, catalyst composition during nanowire growth is measured in situ, as they grow, studied inside an electron microscope and measured by X-ray energy dispersive spectroscopy.

C. B. Maliakkal et al.

Nature Communications 10, 4577 (2019)

https://doi.org/10.1038/s41467-019-12437-6

CELL MEMBRANES, QUANTUM DROPLETS AND CRYSTAL GROWTH

No fewer than three professors affiliated to NanoLund have been named Wallenberg Scholars: Stephanie Reimann, Fredrik Höök and Kimberly Dick Thelander. Stephanie Reimann intends to develop and use advanced quantum mechanical models and computation methods to gain a better understanding of how quantum gases and fluids behave. Fredrik Höök's project aims to improve disease diagnostics by studying microvesicles from cell membranes, and inspire new ways of developing and administering medication, and may also answer fundamental questions about the properties of nanoparticles. Kimberly Dick Thelander explores fundamental processes in crystal growth using a unique in-situ transmission electron microscopy system integrated with chemical vapor deposition for real-time observation of dynamic processes in semiconductor growth.

FIGHTING TYPE 2 DIABETES AND ALZHEIMER'S

Sara Linse has been awarded 10 MDKK from the Novo Nordisk Foundation for her project "Unravelling the IAPP aggregation mechanism for the design of inhibitors that specifically suppress toxicity and cell death in type 2 diabetes" as part of the Foundation's Research Leader Programme. The hormone IAPP is produced, stored and released together with insulin, and is in most type 2 diabetes cases found in aggregated form, causing death of the insulin-producing cells. "Current efforts to develop inhibitors against IAPP aggregation are spent without knowledge of the underlying mechanism. This is where this project comes in," says Sara Linse. She recieved the "FEBS | EMBO Women in Science Award 2019" in part for her work on the molecular mechanisms of protein self-assembly in Alzheimer's disease and related neurodegenerative disorders.

Photo: Mikael Risedal

SYNTHESIS AND APPLICATIONS TOWARD GREEN AND RED LIGHT-EMITTING DIODES

To realize white solid-state lighting by combining nitride LEDs of all three primary colors, highly efficient green and red, nitride LEDs are desirable. However, this is hard to achieve due to lattice mismatch and strain. This work presents a method for synthesizing arrays of InGaN submicrometer platelets by selective-area MOVPE combined with a reformation process step that turns the pyramidal shape into a hexagonal platelet. Such platelets offer surfaces with relaxed lattice constants, thus enabling shifting the quantum well emission from blue (as when grown on GaN) to green and red. On the basis of this method, prototype light-emitting diodes were demonstrated with green emission on $In_{0.09}Ga_{0.91}N$ platelets and red emission on $In_{0.18}Ga_{0.82}N$ platelets.

Z. Bi, et al.
Nano Letters 19, 2832-2839 (2019)
https://doi.org/10.1021/acs.nanolett.8b04781

SINGLE-MOLECULE DETECTION WITH LIGHT-GUIDING NANOWIRES

Determining the surface concentration and diffusivity of cell-membrane-bound molecules is central to the understanding of numerous important biochemical processes taking place at cell membranes. This study uses the high aspect ratio and lightguiding properties of semiconductor nanowires to detect the presence of single freely diffusing proteins bound to a lipid bilayer covering the nanowire surface and expands the rapidly growing use of semiconductor nanowires in various bioanalytical sensor applications and live cell studies.

D. Verardo et al.
Nano Letters 19, 6182-6191 (2019)
https://doi.org/10.1021/acs.nanolett.9b02226

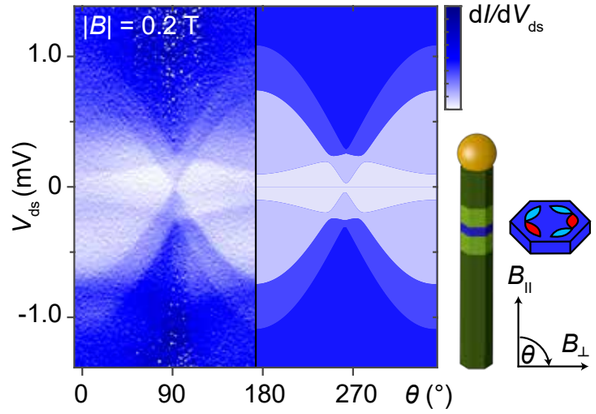
NANO RISK AT ALMEDALEN

Effective protection of people and the environment requires risk management to span the entire life cycle of nano materials, from initial design, over production and use, to end-of-life recycling, destruction or dispersion. This perspective on nano safety risk management cuts through the catalogue of projects at NanoLund, and has been specifically addressed at the annual democratic meeting place Almedalen.

Electrical control of spins and giant g-factors in ring-like coupled quantum dots

Emerging theoretical concepts for quantum technologies have driven a continuous search for structures where a quantum state, such as spin, can be manipulated efficiently. By using small electric and magnetic fields, a mechanism for spin and orbital manipulation is presented. By hybridizing specific quantum dot states at two points inside InAs nanowires, nearly perfect quantum rings form. The orbital contributions can be efficiently quenched by simply detuning the individual quantum dot levels with an electric field. In this way, we demonstrate not only control of the effective g-factor from 80 to almost 0 for the same charge state, but also electrostatic change of the ground state spin.

H. Potts et al.
Nature Communications 10, 5740 (2019)
https://doi.org/10.1038/s41467-019-13583-7



Experimental measurement and theoretical calculation of quantum ring states as a function of magnetic field direction.

European Research Council grants to lasers and quantum systems

Åsa Haglund, NanoLund affiliated member at Chalmers University, has won an European Research Council consolidator grant with the title: "UV-LASE: Out of the blue: membrane-based microcavity lasers from the blue to the ultraviolet wavelength regime", including support of approximately 2 M€. Martin Leijnse and his three colleagues at Copenhagen University received in total 10 M€ for an ERC Synergy project called "Foundations of nonlocal and nonabelian condensed-matter systems", where they aim to experimentally demonstrate properties that have been predicted and heavily studied theoretically for more than three decades.

BETTER HARVESTING OF SOLAR ENERGY WITH IRON

Researchers within NanoLund investigate how iron-based molecules can be used in the development of solar cells and solar fuel. The aim is to replace expensive and rare metals such as ruthenium, osmium and iridium with iron-based photocatalysts. Kenneth Wärnmark was awarded 35 MSEK från the Knut and Alice Wallenberg Foundation for the project "Photofunctional iron complexes". In addition, a study lead by Jens Uhlig found that one third of the energy in a certain type of light-absorbing iron molecule disappears in a previously unknown manner. By closing this loophole, the researchers hope to contribute to the development of more efficient solar cells using this iron-based solar cell.

K. Kunnus et al.
Nature Communications 11, 634 (2020)
https://doi.org/10.1038/s41467-020-14468-w

RADIATION TOLERANT NANOWIRE ARRAY SOLAR CELLS

Space power systems require photovoltaics that are lightweight, efficient, reliable, and capable of operating for years or decades in space environment. Radiation tolerance, combined with the efficient optical absorption and the improving performance of nanowire photovoltaics, indicates that nanowire arrays could provide a pathway to realize high-specific-power, substrate-free, III–V space solar cells with substantially reduced shielding requirements. More broadly, the exceptional reduction in radiation damage suggests that nanowire architectures may be useful in improving the radiation tolerance of other electronic and optoelectronic devices.

P. Espinet-Gonzalez et al.
ACS Nano 13, 12860-12869 (2019)
https://doi.org/10.1021/acsnano.9b05213

Illustration: Kevin A. Gieselman, Kordite, Flickr.com

THERMOELECTRICALLY COOLED THZ QUANTUM CASCADE LASER OPERATING UP TO 210 K

This study presents a terahertz quantum cascade laser operating on a thermoelectric cooler up to a record-high temperature of 210.5 K. The active region design is based on only two quantum wells and achieves high temperature operation thanks to a systematic optimization by means of a nonequilibrium Green's function model. Laser spectra were measured with a room temperature detector, making the whole setup cryogenic free. At low temperatures (~40 K), a maximum output power of 200 mW was measured.

L. Bosco et al.
Applied Physics Letters 115, 010601 (2019)
https://aip.scitation.org/doi/10.1063/1.5110305

NANOLUND SPIN-OUT CELLEVATE NAMED COMPANY OF THE YEAR

Cellevate AB, a company spun out from a project at the Engineering Nanoscience Program at Lund University, was named Nordic Nanotech Company of the Year 2019 at the NanoForum 2019 conference arranged by SwedNanoTech – Sweden's umbrella organization for the Swedish nanotechnology actors. Cellevate provides life science researchers with more realistic in-vitro models. The jury emphasized the high societal value created by significantly reducing the cost of new drug development. Among the three finalists was yet another company spun-out from from our research environment: Hexagem AB.

COMBINING NANOFOCUSED X-RAYS WITH ELECTRICAL MEASUREMENTS AT THE NANOMAX BEAMLINE

By combining the three techniques of scanning transmission X-ray microscopy (STXM), X-ray fluorescence (XRF) and X-ray diffraction (XRD) with simultaneous electrical measurements, further insight into semiconductor devices can be achieved. The system for electrical biasing and current measurement of single nanostructure devices has been developed for the NanoMAX beamline at the fourth-generation synchrotron, MAX IV in Lund.

L. Chayanun et al.
Crystals 9, 432 (2019)
https://doi.org/10.3390/cryst9080432

2019 Visibility worldwide

LEGEND Invited Talks

In 2019, NanoLund scientists have collectively been to 19 different countries presenting our scientific work in nanoscience. A total of 71 invited talks, of which 12 were keynote or plenary talks were presented. A few selected talks are highlighted here.

SCIENTIFIC TALKS | 2019

INVITED TALKS, OF WHICH 71

KEYNOTE & PLENARY 12

Arkady Yartsev
Plenary
International Conference on Ultrafast Optical Science
Moscow, Russia
Understanding of charge carrier dynamics in semiconductors: importance of concerted spectroscopy techniques

Peter Samuelsson
Invited talk
College on Energy Transport and Energy Conversion in the Quantum Regime
Trieste, Italy
Nanoscale Quantum Calorimetry and Electronic Temperature Fluctuations

Bengt Sundén
Keynote
International Summer School on Smart Energy Systems
Harbin, China
On Hydrogen, Batteries and Fuel Cells in Future Smart Energy and Power Systems

Tommy Nylander
Invited talk
Okinawa Colloids 2019
Okinawa, Japan
Lipid liquid crystalline nanoparticles as enzyme carriers –structure and intermolecular interaction controlling the enzyme encapsulation

Kimberly Dick Thelander
Invited talk
Gordon Research Conference on Crystal Growth
Manchester, USA
Exploring 1D semiconductor crystal growth at the nanoscale using in-situ TEM

Martin Magnusson
Invited talk
Nanowire Week 2019
Pisa, Italy
Aerotaxy for mass production of nanowire materials – growth and modeling

Joakim Pagels
Invited talk
EOH-NANO 2019
Loen, Norway
Characteristics and measurement of carbonaceous ultrafine particles – Implications for toxicology

Adam Burke
Invited talk
14th IEEE Nanotechnology Materials and Devices Conference 2019
Stockholm, Sweden
Quantum dot heat engines and hot-carrier solar cells

Anders Mikkelsen
Keynote
32nd European Crystallographic Meeting
Vienna, Austria
Crystal phase control in nanostructures as a platform for atomic scale tailoring of electronic, optical and chemical properties.

Christelle Prinz
Invited talk
21th International Vacuum Congress
Malmö, Sweden
Bio-applications of semiconductor nanowires

Kenneth Wärnmark
Invited talk
XXXVII Reunión Bienal de la RSEQ
Donostia-San Sebastián, Spain
FeCarbenes as photo functional devices

Maria Messing
Invited talk
European Aerosol Conference 2019
Gothenburg
Designing Engineered Nanoparticles: From Sparks to Magnetic, Catalytic and Optoelectronic Materials

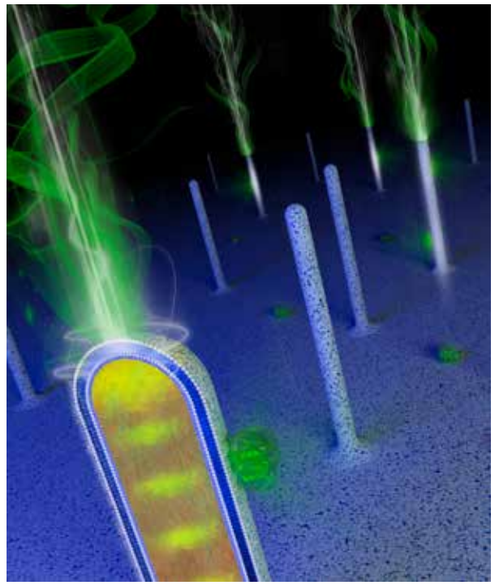
Innovation and collaboration

COLLABORATION WITH INDUSTRY

It is a central, long-term aim for NanoLund to establish a broad and sustainable network of stakeholders in industry, institutes and society. Our vision is to create a forum where companies meet other companies, scientists and stakeholders and find their future employees among our undergraduate and PhD students. To achieve this, we kicked off the NanoTechNow Network in September 2019 with a workshop that engaged representatives from 28 external organizations. Based on the discussions we identified three areas where there is an immediate industry demand and where we can contribute:

- Collaboration and competence in nanosafety and safe-by-design
- Collaboration and services in characterization of materials, including gateway activities for MAX IV
- Workshops on specific innovation areas, to define joint challenges and set quantitative aims

NanoLund has secured initial funding for network activities during 2020 from the Region Skåne and Lund University. To meet the expressed need for knowledge about safety, our course on nanosafety, originally developed for PhD students, will also be offered for professionals as commissioned education starting in spring 2020. In order to reach professionals in industry with research findings and other relevant information from NanoLund a LinkedIn-channel was initiated in May. By the end of the year nearly 1000 people had signed up to follow news, activities and career opportunities posted by NanoLund.



NEW CONCEPTS – NEW IDEAS

NanoLund aims to identify and develop applications of nanoscience that make a positive impact on society and help address needs and challenges. Researchers within NanoLund are encouraged to validate how research results can be utilized for new concepts and ideas with relevance for society and industry. We support innovation and are very proud of all the companies spun out of NanoLund – as many as 29 companies since the start in 1988. Some highlights from 2019:

Two new companies were initiated. AlixLabs aims to provide the nanoelectronics industry with a new, more precise and efficient method to manufacture nanostructures below 20 nm. AligND Systems develops a biosensor platform for detection of single molecules based on the light guiding properties of semiconducting nanowires. AligND Systems secured intellectual properties from the spin-off solar cell company SolVoltaics, that unfortunately went out of operation during 2019.

The NanoLund spin-off companies altogether secured private and/or public investments in the amount of at least 378 MSEK during 2019 in order to take their technologies to market.

NanoLund's spin-off companies operate at the absolute forefront of applied nanotechnology and rely on knowledge and skills generated by academic research and education. It is therefore promising for future technological development that researchers within NanoLund continue to attract major funding for excellent research also in areas where we already see applications. One such example from 2019 is the long-term funding by the Swedish Research Council awarded to Prof. Thomas Laurell for research aiming to develop the technology acoustophoresis. The spin-off company AcouSort already applies the technology to separate whole cells for diagnostic purposes. The group can now take additional steps to explore how acoustophoresis can be developed to capture nanoscale extracellular vesicles for future breakthroughs in early detection of disease.

Spin-off companies from NanoLund (companies in operation as of December 2019, in alphabetical order)

COMPANY		Starting year	Number of employees 2018
Acconeer	Develops unique radar solutions based on pulsed coherent radar technology combining extremely low energy consumption with high accuracy.	2011	25
AcouSort	Combines acoustics and microfluidics to separate and sort cells and particles in biological and clinical samples.	2010	5
AligND Systems	Utilizes the light-guiding properties of semiconductor nanowires to develop a biosensor platform for analyzing biomarkers such as proteins and other molecules.	2019	-
AlixLabs	Provides a method to manufacture nanostructures with a characteristic size below 20 nm for the electronics industry.	2019	-
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	8
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	1
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	2
Glo	Develops LEDs in the colors red, green and blue using III-nitride-based nanowires.	2003	47
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	0
NeuroNano	Develops innovative electrodes for deep brain stimulation (DBS) with the aim to improve the quality of life for people with various neurological illnesses.	2006	2
Obducat	Develops and supplies lithography solutions for production and replication of advanced micro- and nanostructures for industrial needs.	1989	43
Spermosens	Develops a diagnostic technology for male infertility aiming to predict the outcome of in-vitro fertilizations.	2018	0
Thyrolytics	Develops a diagnostic tool for measuring thyroid hormones in blood.	2018	0
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	3
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	No available data

Infrastructure

LUND NANO LAB – MYFAB LUND

Lund Nano Lab (LNL) is one of the main resources within NanoLund and provides support to research groups in strategically important fields of materials science, nanotechnology, microelectronics, life science and quantum technology.

LNL is an open research facility that is available to academic research groups, start-up and company users. Our world-class clean room facility is equipped with state-of-the-art semiconductor processing and metrology equipment. LNL is staffed with metrology, equipment and process experts who are available to train and guide users. We also educate students enrolled at Lund University and participate in outreach activities for the local community and society. LNL is a member of Myfab, the Swedish Research Infrastructure for Micro and Nano Fabrication since 2016.

KEY FEATURES OF LNL:

- ISO 5 and ISO 7 cleanroom facility for cutting edge nano- and micro-fabrication
- 24/7 access for accredited academic research and company users
- Fabrication and analysis of structures on the micro- and nanometer-scale
- Wide range of equipment for growth, lithography, deposition, etch and characterisation
- Centre of excellence for epitaxial growth of III-V materials
- Industrial product development and prototype testing
- Staffed by equipment and process experts available to provide user training

Photo: Kenneth Ruona

Luke Hankin, Head of LNL.

NCHREM – NATIONAL CENTER FOR HIGH-RESOLUTION MICROSCOPY

The nCHREM facility is situated within the Chemical Center at Lund University and has state-of-the-art tools for electron microscopy, including a unique Environmental TEM for in-situ experiments. We offer expertise in imaging, element analysis, and sample preparation for a wide variety of sample types. The nCHREM also provides equipment for specimen preparation, image calculation, processing and documentation, including equipment for plunge-freezing of liquids and cryogenic imaging. We have experience in problem solving and many industrial partners have used our expertise. The facility has analysed all kinds of materials from biological samples to high-tech electronic components. The active time on the available instruments is well distributed between many different users within Lund University, external users and teaching. The nCHREM facility is also part of the Lund Nano Characterisation Lab.

LUND NANO CHARACTERISATION LABS

NanoLund possesses an extremely wide range of cutting-edge characterization techniques ranging from microscopes capable of single-atom imaging to ultrafast spectroscopy labs with capability of tracking processes on a femtosecond time scale. These characterization laboratories are distributed all across Lund University. NanoLund's interdisciplinary environment spans the departments of physics, chemistry, biology, medicine, and electrical engineering at Lund University.

Researchers at these departments are carrying out groundbreaking methodological developments in areas such as: electrical and optical nano-characterization, multidimensional laser spectroscopy, scanning probe microscopy, transmission electron microscopy, synchrotron-based imaging, spectroscopy and scattering, nanosafety, biocompatible nanoelectrodes, as well as many-body and transport theory.

The NanoLund community also uses major cutting-edge characterization facilities at Large scale Research Infrastructures (LRIs), such as the MAX IV synchrotron in Lund. NanoLund members are also frequent users of neutron facilities worldwide and collaborate with the European Spallation Source (ESS) in Lund. Additionally, some members are actively involved in the development of new instrumentation at MAX IV and other LRIs.

Photo: Charlotte Carlberg Bärg

STATISTICS | LNL 2019

USERS WITH ACCESS	303
ACTIVE USERS	142
UNIVERSITY ACTIVE USERS	126
INSTITUTES ACTIVE USERS	2
COMMERCIAL ACTIVE USERS	14
HOURS BOOKED	51 254
NUMBER OF TOOLS	98
BOOKABLE TOOLS	75

Education

UNDERGRADUATE EDUCATION

The Engineering Nanoscience Programme at the Faculty of Engineering is a complete five-year degree programme that starts at university entrance level and leads to a Master's degree. It was initated in 2003 by NanoLund scientists and symbiotically combines education and research, with strong industry connections. Teaching is driven by high-level research activities in the field and there are possibilities to obtain industry experience through projects and internships. In turn, research and industry benefits from the highly qualified graduates leaving the programme. It provides a holistic perspective of nanoscience and, in fact, of engineering and natural sciences, including biology, biochemistry, medicine, physics, math and chemistry. The last few years NanoLund has strived for increased interactions also with other undergraduate education programmes. For example, since 2017 more than 150 undergraduate students from several different education programmes have signed up as NanoLund student members. A number of events have been organized for the student members, including yearly joint retreats with NanoLund PhD students and postdocs, talks and mingle with NanoLund alumni, scientific talks by young NanoLund scientists and an information event about Master's projects at NanoLund.

ENGINEERING NANOSCIENCE STATS | 2019

STUDENTS STARTED, OF WHICH	44
WOMEN (32%)	14
MEN (68%)	30
GRADE POINT AVERAGE NEEDED FOR HIGH SCHOOL STUDENTS	19.1
STUDENTS GRADUATED, OF WHICH 13 WOMEN AND 22 MEN	35

In addition, NanoLund has sponsored four nanoscience students to attend the conference INASCON in 2019 in Beijing, China. Some of these students now lead the work in organizing INASCON 2020 in Lund with support from NanoLund.

Photo: Kenneth Ruona

Outreach

REACHING OUT TO THE COMMUNITY

Many NanoLund members have been involved in a variety of different types of external engagement throughout the year. This involvement is well in line with our long-term strategic goal to include a majority of our members in outreach activities. The most common action has been popular scientific lecturing; several hundred high school students, the general public and companies in the region have learned about the opportunities offered by nanotechnology. Our members have also been involved in educating high school teachers, developed a theatre performance followed by a workshop with practical lab exercises, and participated in science slams. In addition, NanoLund's research results have been widely spread during the year through several press releases, in printed newspapers, and via features on radio and TV.

OUTREACH STATS | 2019

ONLINE ARTICLES AND PRESS RELEASES	72
PRINTED ARTICLES	33
RADIO FEATURES	5
POPULAR SCIENCE TALKS	72
OF WHICH FOR JUNIOR TO HIGH SCHOOL STUDENT	26
COMMISSIONED EDUCATION COURSE	1
CONTRIBUTION TO SPECIALIST NEWSPAPER	1
THEATRE AND WORKSHOP	1

TWITTER:
32 tweets generated 59000 tweet impressions.

LINKEDIN: Our efforts resulted in 2300 clicks and 24000 unique impressions since the start May 29th. We had close to 1000 LinkedIn followers by the end of 2019.

The scientifical studies of nanoplastics by Tommy Cedervall became a theatre play, "The Way to Go", interpreted by actor Torbjörn Lindgren.

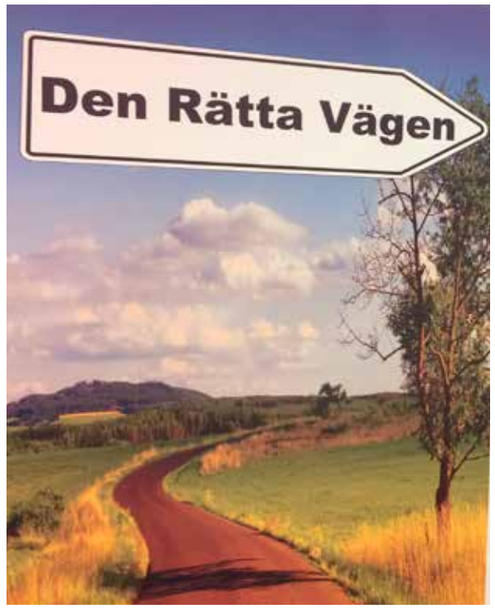


Photo: Line Lundfald

2019 NanoLund Awards

Photo: Ivan Maximov

NANOLUND AWARD FOR EXCELLENT TECHNICAL AND ADMINISTRATIVE SUPPORT:

The excellent work done by technical and administrative support staff is of critical importance for NanoLund, and none of our work in teaching and research would be possible without it. This award recognizes outstanding achievements for technical and administrative personnel. This year's award was presented to:

Johanna Mosgeller, System Administrator, Solid State Physics for a great combination of IT skills, effectiveness and smile.

George Rydnemalm, Lab Technician, Solid State Physics for always being very helpful and dedicated.

NANOLUND YOUNG TEACHER AWARD:

Teaching is a very important part of our mission, and we are proud of the achievements by our young teachers. This award recognizes extraordinary commitment to teaching by junior scientists. In 2019 it was presented to:

Calle Preger, PhD student, Solid State Physics. Calle is teaching in the course Thermodynamics with Applications as well as other courses. Every year he is highly praised in course evaluations for his pedagogic skills. He always shows patience and makes students comfortable in asking questions and never gives up until the students understand.

Florinda Viñas Boström, PhD student, Solid State Physics. Florinda has been a lab instructor and tutor in Electronic Materials during several years. She is highly appreciated by students for her significant pedagogic skills. She is ambitious in fulfilling the teaching goals with a high sense of duty.

NANOLUND JUNIOR SCIENTIST IDEAS AWARD:

NanoLund seed projects give junior scientists (master students, PhD students and postdocs) the opportunity to propose and carry out new projects that are complementary to existing research directions in NanoLund. In the 2019 project call, 11 projects were received and evaluated by a group of senior scientists and PhD students, with an emphasis on originality, feasibility and potential impact. Four projects were selected for funding by a one-time sum of 100 000 SEK each for research expenses:

Namsoon Eom, Postdoctoral fellow at Solid State Physics – Nanoparticle superlattice growth using evaporative self-assembly.

Lukas Bruder, Postdoctoral fellow, Chemical Physics & Lukas Wittenbecher, PhD student, Synchrotron Radiation Research – Ultrafast hot-carrier dynamics at semiconductor heterojunctions resolved in energy, time and space.

Mohamed Abdellah, Researcher, Chemical Physics – CO_2 photoreduction by molecular Re(I) catalyst/InP nanowires system, dynamics and catalytic activity.

Yang Chen, Postdoctoral fellow, Solid State Physics – Solar windows – Transparent solar cells.

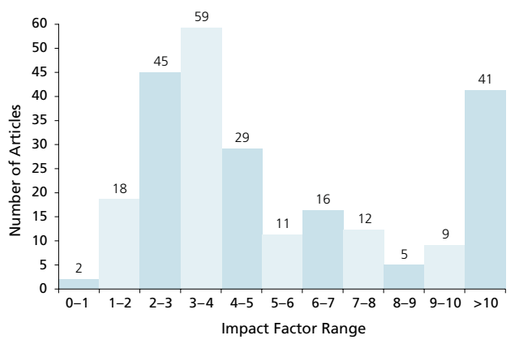
Scientific publications

SCIENTIFIC PROGRESS

Our most important way of communicating our results and providing value to the scientific community is through high-quality scientific publications in widely cited, peer reviewed journals. In 2019, we saw a significant increase of the number of publications, reaching now 419, compared to 305 in the previous year, possibly in part due to a greater effort in careful reporting as a consequence of an internal research quality study at Lund University. The quality of our publications remained high, with an averaged journal impact factor (JIF) of 6.0, averaged over all our publications relevant to nanoscience. As many as 17% of these publications were published in journals with a journal impact factor larger than 10. The overall distribution of the journal impact factor remains similarly shaped compared to the last years. We consider it a very 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.

Photo: Kennet Ruona

Journal Impact Factor (JIF) distribution for NanoLund poublications 2019 (247 of 286 nanoscience publications have a well-defined JIF)



METRICS | 2019

PUBLICATIONS IN TOTAL, OF THESE	419
SPECIFICALLY IN NANOSCIENCE, AND OF THESE	286
WITH JOURNAL IMPACT FACTOR (JIF) > 10	41
NATURE, NATURE FAMILY, SCIENCE & PNAS, AND	8
NANO LETTERS.	12
AVERAGE IMPACT FACTOR	6.0

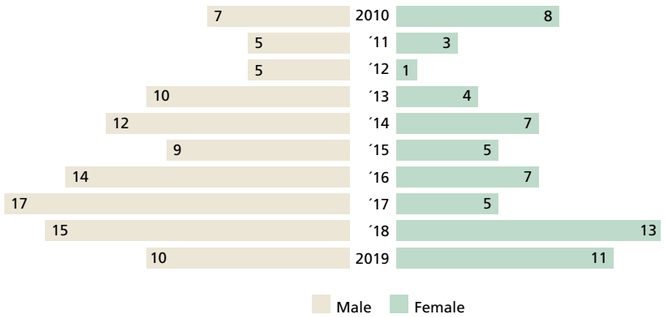
Graduate education

GRADUATE EDUCATION AT NANOLUND

NanoLund is Sweden's largest research environment for interdisciplinary nanoscience and nanotechnology. In 2019, we engaged as many as 148 PhD students in thesis projects ranging from engineering to natural sciences and medicine. Below are the trends for completed doctoral theses from 2010 onwards, with gender specific statistics.

We are very proud of our 21 PhDs graduated in 2019 and wish them all a brilliant career!

NanoLund PhD Theses 2010–2019



Anke Urbansky
Biomedical Engineering
Acoustofluidic preparation of whole blood components

Frida Lindberg
Solid State Physics
Technology for biocomputational devices based on molecular motors

Jovana Colvin
Synchrotron Radiation Research
Scanning probe techniques as an investigation tool for semiconductor nanostructures and devices

Laura Aaltonen
Radiology Diagnostics
Measuring distal airspace dimensions with nanoparticles. Initial development of a diagnostic method.

Linda Månsson
Physical Chemistry
Synthesising colloidal molecules with tunable interactions from soft responsive microgel particles

Maria Valldeperas Badell
Physical Chemistry
Lipid sponge phase nanostructures as carriers for enzymes

Maryam Khalilian
Solid State Physics
Novel architectured, dislocation-free, III-Nitride structures for the next generation optoelectronic devices

Sara Kheradsoud
Mathematical Physics
Thermoelectric Effects and Single Electron Sources in Mesoscopic Transport; a Scattering Approach

Sofie Yngman
Synchrotron Radiation Research
Semiconductor Nanowires: Characterization and surface modification

Xiaojun Su
Chemical Physics
Charge Carcier Dynamics in Low Dimensional Opto-electronic Semiconductors

Kalyani Sanagavarapu
Biochemistry and Structural Biology
On the molecular mechanisms of the amyloid β-peptide aggregation

Andrea Troian
Synchrotron Radiation Research
Synchrotron X-ray based characterization of technologically relevant III-V surfaces and nanostructures

Bekmurat Dalelkhan
Solid State Physics
Charge transport in III-V narrow bandgap semiconductor nanowires

David Göransson
Solid State Physics
Strain and Charge Transport in InAsP-InP and InP-InAs Core-Shell Nanowires

Feifei Peng
Physical Chemistry
A microfluidic toolbox to fabricate, sort and characterize thermoresponsive colloidal molecules and their assemblies

Fredrik Brange
Mathematical Physics
Quantum Correlations and Temperature Fluctuations in Nanoscale Systems

MA Rahman
Chemistry and Biomedical Sciences
Biophysical studies of the actin-myosin motor system and applications in nanoscience

Payam Shayesteh
Synchrotron Radiation Research
Atomic Layer Deposition and Immobilised Molecular Catalysts Studied by In and Ex Situ Electron Spectroscopy

Trung Tran
Solid State Physics
Deterministic Lateral Displacement for Cell Separation

Zhen Cao
Heat Transfer
Pool Boiling on Structured Surfaces: Heat Transfer and Critical Heat Flux : -Experiments and Mechanistic Modelling

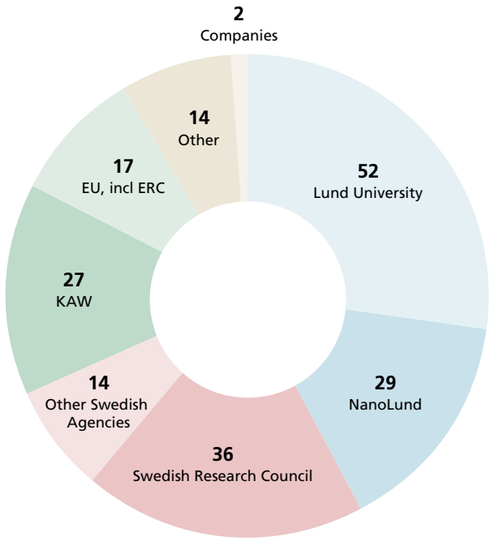
Jasper Immink
Physical Chemistry
Fluids, Gels and Crystals: Phase behavior of binary thermoresponsive microgel mixtures

Funding

NANOLUND INCOME SOURCES FOR 2019

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

The total income is evaluated as the income of members, weighted with their degree of participation in NanoLund.



NanoLund Income Sources 2019 (MSEK)

INCOME IN MSEK | 2019

201 total income, of which

81 from the University, including

29 Strategic Research Area funding for NanoLund

120 is external funding won in competitive calls. Breaking down the individual contributions there is about

36 from the Swedish Research Council (VR),

27 from the Knut and Alice Wallenberg foundation (KAW),

17 from EU funding including ERC,

14 from other Swedish funding agencies, (such as the Swedish Foundation for Strategic Research (SSF) and the Swedish Energy Agency)

14 from other grants,

2 from companies.

EUROPEAN FUNDING

The NanoLund environment continues to be active on a European level, applying for individual grants and collaboration projects. In 2019 members of NanoLund:

- Held 5 active ERC grants and had 2 granted for start during 2020
- Participated in 12 EU projects
- Coordinated 2 EU projects and had 1 granted for start during 2020
- Held 2 Marie Skłodowska-Curie Individual Fellowships

OTHER PRESTIGIOUS FUNDING:

NanoLundians also hold a number of highly prestigious grants:

- Four Wallenberg Scholars,
- Four KAW projects,
- One Novo Nordisk Foundation project,
- Three Swedish Research Council Distinguished Professor, and
- Five Swedish Research Council Research Environments

A great big Thank you to those who fund our research!

LIST OF FUNDING BODIES

AFA Insurance
Alzheimerfonden
Candle Innovation
Carl Tryggers stiftelse för vetenskaplig forskning
The Crafoord Foundation
European Commission's Research and Innovation Activities: European Research Council (ERC), Marie Skłodowska-Curie Actions, Horizon 2020 and FP7
Formas
Forte Swedish Research Council for Health, Working Life and Welfare
Hjärnfonden
The Kamprad Family Foundation for Entrepreneurship, Research & Charity
KMA – Stiftelsen Kronprinsessan Margaretas Arbetsnämnd för synskadade
The Knut and Alice Wallenberg Foundation
LMK –stiftelsen Foundation for Interdisciplinary Scientific Research
Mats Paulssons Stiftelse för forskning, innovation och samhällsbyggande
Michael J. Fox Foundation for Parkinsons's research
The Swedish foundation for strategic environmental research, Mistra
The National Research Center for the Working Environment (NFA) in Denmark
The Novo Nordisk Foundation
Olle Engkvists stiftelse
Region Skåne
The Royal Physiographic Society of Lund
Sida – Swedish International Development Cooperation Agency
STINT – The Swedish Foundation for International cooperation in Research and Higher Education
The Swedish Energy Agency
Swedish Environmental Protection Agency
The Swedish Foundation for Strategic Research
The Swedish Heart-Lung Foundation
The Swedish Research Council
Swedish Water Research
Swedish Work Environment Authority
Sydvatten AB
Vinnova
Volkswagenstiftung
Wenner-Gren Foundations
Åhlén-stiftelsen


Photo: Kennet Ruona

Organisation

HOW NANOLUND IS SET UP

NanoLund is the Center for Nanoscience at Lund University and a Strategic Research Area funded by the Swedish government. Engaging more than 50 research groups in the faculties of Engineering (LTH), Science and Medicine, we are Sweden's largest research environment for nanoscience and nanotechnology.

NanoLund's vision is to be a world-leading research center that uses the unique opportunities offered by nanoscience to advance fundamental science and to address societal challenges. To realize our vision, we are organized into seven research areas:

- Materials Science
- Quantum Physics
- Nanoelectronics & Nanophotonics
- Nanoenergy
- Nanobiology & Neuronanoscience
- Nanosafety
- Exploratory Nanotechnology

Our scientific work is enabled and complemented by our two infrastructures Lund Nano Lab (LNL), and Lund Nano Characterization Labs (LNCL), as well as by our strong engagement in education. The allocation of resources and the development of strategic aims in each area is coordinated by a team of two experienced faculty members.

NanoLund is headed by a Board, which defines strategy and makes formal decisions. The center is advised by an international Scientific Advisory Board and by an External Advisory Council from society, academia and industry.

During 2016–2020 NanoLund works with the following longterm strategic aims:

Highly controlled nanostructures
To realize, model and characterize nanostructures, devices and systems with atom-level control.

Fundamental science for future devices
To discover fundamental physics, materials science and paradigms that may lead to future energy and Information and communications technology devices with enhanced performance.

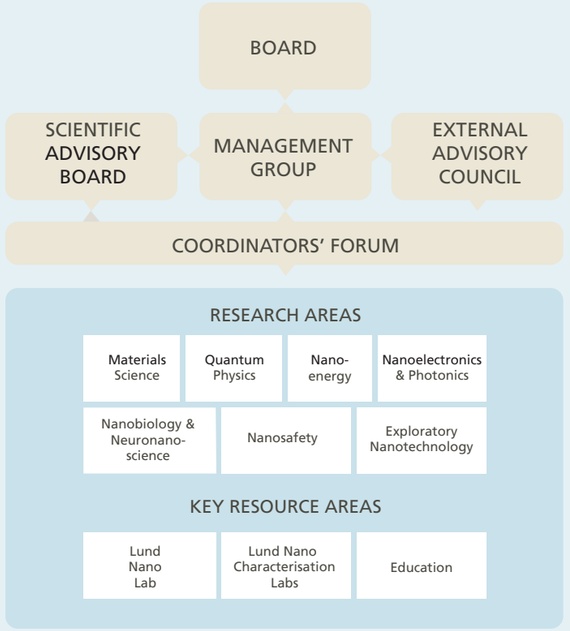
Tools for single-cell biomedicine
To develop sensors, probes, stimulators and single-molecule methods for single- and few-cell biomedicine.

A Great Place to do Nanoscience
To be an internationally highly visible nanoscience center that offers exceptional scientific opportunities, training and career development.

Nanomaterials industry
To establish an ecosystem that integrates education, research, R&D and pilot production to take ideas from research to the marketplace.


Photo: Kennet Ruona

NANOLUND SCIENTIFIC ADVISORY BOARD Henning Riechert | Chris Palmstrøm | Friedrich Simmel | Stephen Goodnick | Ulla Vogel | Chi-Chang Kao (missing: Evelyn Hu).



NANOLUND BOARD MEMBERS:
Viktor Öwall, *(Chair), Dean, LTH* | Thomas Hønger Callisen, *Novozymes* | Braulio Antonio Chi, *Student representative* | Peter Honeth, *former State Secretary* | Erik Lind, *LTH* | Heiner Linke, *Director, NanoLund* | Sara Linse, Science faculty | Camilla Modéer, *IVA* | Kristian Pietras, *Medical faculty* | Kimberly Dick Thelander, *LTH* | Mattias Åstrand, *Student representative*

2019 MANAGEMENT GROUP: Heiner Linke *Director* | Anders Mikkelsen *(Vice-Director)* | Anneli Löfgren *(Co-Director)* | Martin Leijnse | Tommy Nylander | Christelle Prinz | Ivan Scheblykin | Lars Samuelson *(Senior Strategic Advisor)*

2019 SCIENTIFIC ADVISORY BOARD: Stephen Goodnick, *Arizona State University* | Evelyn Hu, *Harvard* | Chi-Chang Kao, *SLAC/ Stanford University* | Chris Palmstrøm, *UC Santa Barbara* | Henning Riechert, *Paul Drude, Berlin* | Friedrich Simmel, *TU München* | Ulla Vogel, *NFA, Denmark*

2019 EXTERNAL ADVISORY COUNCIL: Camilla Modéer *(Chair), IVA* | Ola Asplund, *IF Metall* | Lars Börjesson, *Chalmers University* | Peter Honeth, *former State Secretary* | Per Krokstäde, *IKEA* | Daniel Kronmann, *Region Skåne* | Anna Stenstam, *CR Competence*

Photo cover and back: Charlotte Carlberg Bärg

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This Annual Report 2019 for the NanoLund research environment at Lund University presents scientfic, educational, outreach and public impact highlights, progress, data, and trends for and up to 2019. This report is based on material and data compiled and edited by the staff of NanoLund, in particular: **Line Lundfald,** Communications and Coordination | **Evelina Lindén,** Communication | **Anna-Karin Alm,** External Relations Officer | **Anneli Löfgren,** Administrative Director | **Heiner Linke,** Director

To order a paper version of the NanoLund Annual Report 2019, please contact info@nano.lu.se

LUND UNIVERSITY

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CENTER FOR NANOSCIENCE

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