A Great Place to do Nanoscience

NanoLund is the internationally recognized, cross-disciplinary Center for Nanoscience at Lund University in Sweden.

We bring together around 270 researchers from the engineering, natural science and medical faculties at Lund University. Our common goal is to push back the frontiers of nanoscience and help realize its full potential to address important societal issues, such as those related to energy, health, and the environment. To that end, we focus on the materials science, safety, fundamental physics, and chemistry of highly controlled, functional nanostructures, with a particular emphasis on nanowires and their applications.

“Our vision is to be a world-leading research center that uses the unique opportunities offered by nanoscience to advance fundamental science and to address society’s grand challenges.”

Prof. Heiner Linke, Director, NanoLund

HISTORY

1988 Lars Samuelson initiates the Nanometer Structure Consortium (nmC)
1990 nmC funded by NFR, NUTEK, and later, SSF
2000 Nanowire research initiated
2003 5-year degree program Engineering Nanoscience launched
2005 Recognized as one of Sweden’s top 10 research environments by VR
2006 Linnaeus Center and graduate school
2007 Inauguration of Lund Nano Lab
2010 Strategic Research Area nmC@LU
2015 nmC@LU evaluated as one of the top five Strategic Research Areas in Sweden
2015 nmC becomes NanoLund
“Our mission is to bring together the most creative scientists, students, and industry in an interdisciplinary research environment to do cutting-edge research on the materials science, physics, chemistry, and safety of designed functional nanostructures for energy, opto/electronics and life science applications.”

Prof. Lars Samuelson, Founder and Vice-director, NanoLund
Its roots represent our core competences, developed over the past decades. Supported by these roots, the tree’s crown represents the scientific areas where we are active, including materials science and quantum physics. Its branches include a broad range of dynamically growing areas of applied research where we can use our unique, functional nanomaterials and devices to address important societal and scientific problems. This is often done in collaboration with experts in the respective fields.
Materials science lies at the heart of all research activities at NanoLund. This is because the properties of nanostructures are sensitively determined by their size, shape, and crystal structure, and consequently by the conditions under which these structures are realized. Understanding the growth mechanisms is therefore not only of fundamental interest, but also crucial for tailoring nanostructures for applications.

**GROWTH**
Using epitaxial methods such as metal-organic vapour phase epitaxy (MOVPE), we grow nanoscale structures such as nanowires, quantum dots and thin films from a combination of III-V semiconductor materials.

**ADVANCED CHARACTERIZATION**
State-of-the-art microscopy methods such as transmission electron (TEM), atomic force (AFM), scanning tunneling (STM), scanning electron (SEM), and synchrotron X-ray allow us to characterize the internal structure and surface of nanostructures with ultra-high resolution down to the atomic level.

**METHODOLOGICAL DEVELOPMENT**
We work continuously to develop and improve new growth methods such as Aerotaxy – our breakthrough method that is capable of producing nanowires at an unprecedented rate, and that we are now developing into a scalable process for massproduction of nanowires.

**Materials Science**
We aim to understand and control the growth of nanostructured materials with atomic precision.
Physics

We elucidate how quantum physical effects determine the electronic, optical, and thermoelectric properties of nanoscale systems.

Quantum effects arise because of quantum confinement of and many-body correlations between electrons confined to these nanostructures. Understanding such quantum behavior is crucial to understanding emergent microscopic phenomena that are not observable in bulk and to harnessing these quantum effects for the design of advanced nanoscale devices.

QUANTUM OPTICS
Our unique method to probe collective electron excitation and motion with simultaneously subfemtosecond time and sub-nanometer spatial resolution enables us to probe times, energies, and spatial distribution of electron excitations and associated electron dynamics in nanostructures, and correlate these to their structure.

QUANTUM TRANSPORT
We perform experimental and theoretical studies of complex quantum transport phenomena and materials such as topological insulators, Majorana fermion systems, Wigner localization, Kondo physics, and thermoelectric transport.

QUANTUM INFORMATION
Using laser-matter interactions to manipulate electrons’ wavefunction, we create, spatially separate, and detect pairs of entangled electrons. This is vital for quantum computing, communication, and information processing. We achieve this in inorganic crystals, doped with rare-earth ions, and spin-based nanoscale systems to realize qubits and quantum memories.

“Nanoscale systems are versatile playgrounds for studying complex quantum physical phenomena.”

Prof. Stephanie Reimann, Mathematical Physics
Developments leading to the modern information society have relied on the scaling down of conventional silicon-based electronics and photonics concepts. However, this development, following Moore’s ‘law’, cannot continue indefinitely because of physical size limitations. To overcome these limitations, we explore new nanotechnology concepts.

**NANOWIRE ELECTRONICS**
By combining our capabilities for growing high-quality nanowires and state-of-the-art processing and characterization methods, we investigate and optimize electronic devices. Examples include transistors, diodes, and solar cells from III-V, heterostructured and nitride compound semiconductor nanowires.

**SPINTRONICS**
We develop new magnetic semiconductor nanodevices based on Mn-doped III-V nanowires with the aim of combining the two fundamental properties of electrons – charge and spin – to gain efficiency and new functionality. This is useful for next-generation computers, data storage devices, and optical communications solutions.

**PHOTONICS ENGINEERING**
By tailoring material properties, we study bandgap engineering in strained core-shell, segmented, and other types of nanowire-based structures. The aim is to control their optical response for applications in optical communications, thermal sensing, and solar cells, and to understand non-linear optical phenomena such as frequency doubling and photon upconversion.

*Nanoelectronics and Nanophotonics*

We develop nanotechnology of electronic and optoelectronic to boost the efficiency of devices.
Finding more efficient and sustainable methods for harvesting and converting energy into electricity is one of humanity’s greatest challenges. We work to harness the unique electronic, photonic, and structural properties of engineered nanomaterials to realize efficient devices that can collect energy and convert it to useful electricity while using substantially less material than conventional technologies.

PHOTOVOLTAICS
We develop sustainable solar energy solutions based on radial and axial-geometry nanowire photovoltaics with high energy-conversion efficiency, that can be fabricated at a low cost, and that require significantly less material than conventional thin-film solar-cell technologies.

LIGHT EMITTING DIODES (LEDS)
To help alleviate the huge energy consumption associated with lighting, we develop efficient LEDs covering the entire visible spectrum from red to blue, using III-V and III-nitride core-shell nanowires.

THERMOELECTRICS
We explore how the ubiquitous thermal motion of electrons, atoms, and molecules can be used to generate electricity at the micro and nano scale using the principle of thermoelectrics.

“Nanotechnology is crucial for solving the energy-challenges facing society today.”

Prof. Villy Sundström, Chemical Physics
Nanobiology

Our nano-life-science research efforts are geared to unraveling fundamental dynamic cellular mechanisms at the nano scale and using them in applications in biology and medicine.

NEURONANOSCIENCE
Using nanowires, we develop nanoscale electrodes and electro-optical devices for recording and stimulating neural activity. The overall goal is to elucidate dynamic neural and glial mechanisms that are responsible for learning-related changes in the neural network structures and information processing functionality of conscious individuals.

CELL STUDIES
We perform detailed studies to explain how cell behavior, physiology and mechanics change when cells interact with nanostructures. Our aim is to develop novel nanoscale applications in biology and medicine, such as mechanosensing, biopsy, injection, cell differentiation, migration, proliferation, and stimulation.

BIOPHYSICS
By manipulating and controlling molecules and cells at their natural-length scales, we develop novel tools to address urgent needs in biology and medicine for DNA analysis, cell sorting, and cell manipulation at the single-cell level. We also learn how to use molecular motors in devices, for example for diagnostics or computation.

“Nanoscience offers a platform for understanding and addressing important questions and problems in the life sciences, such as unraveling the workings of the brain.”

Prof. Jens Schouenborg, Neuronano Research Center
To ensure a sustainable and safe implementation of nanotechnologies we must first understand their potential impact on society and the environment.”

Nanosafety

We study the risks and health effects associated with nanostructures, in particular focusing on processes related to production, manufacturing, handling, usage, disposal, and recycling.

WORKPLACE EXPOSURE
Because the largest risk of exposure to manufactured nanostructures occurs in work environments, we develop methods for assessment of ‘real world’ exposure levels and properties of emitted particles. We explore their biological effects at the cellular level as well as in humans.

BIOLOGICAL EFFECTS
We study the structural and functional consequences of the interaction between nanostructures and biological molecules in living organisms. The overall aim is to build predictive models for the development of safe nanomaterials.

ENVIRONMENTAL AND SOCIETAL IMPACT
We develop and test existing ecotoxicological methodologies for predicting the effects of engineered nanomaterials on a diversity of systems. The ultimate goal is to develop accurate environmental risk-assessment methods that can be applied at length scales ranging from the cellular level to that of entire ecosystems.
Lund Nano Lab

Lund Nano Lab (LNL) is an open-access, state-of-the-art nanofabrication and characterization facility that is hosted and managed by NanoLund and used by both academic and industry users.

LNL is central to all of NanoLund’s research. It has cleanroom space, equipment, and expertise for cutting-edge nanofabrication and characterization for both fundamental research and device development. It is open to both academic users and start-up companies, providing research infrastructure for scientific research, industrial product development and prototype testing. LNL consists of two interconnected labs for epitaxy and processing.

EPITAXY LAB
The epitaxy lab has advanced tools for ‘bottom-up’ growth of III-V semiconductor (GaAs, InP, antimonides, nitrides, ternary compounds) epitaxial layers, and nanostructures.

PROCESS LAB
LNL’s process lab has all the necessary state-of-the-art tools for ‘top-down’ fabrication and basic characterization of nanostructures.

KEY NUMBERS
Tools: 81
Usage: 54,000 hrs per annum
Users: 147
Distribution: 80% academic and 20% industry

EPITAXY LAB KEY FEATURES
160 m² cleanroom (ISO 7)
4 MOVPE – epitaxial growth
3 ALD – deposition of dielectric layers
2 SEM – high-resolution imaging

PROCESS LAB KEY FEATURES
180 m² cleanroom (ISO 5)
2 EBL – high-resolution (~15–20 nm) patterning
NIL – nanopatterning of 6-inch wafers
FIB/SEM - FIB with 1.1 nm resolution SEM
Anti-vibration platforms
Researchers within NanoLund are heavily involved in designing, developing, and refining cutting-edge nanocharacterization tools, both in Lund and at an international level. LNCL integrates all of these efforts to give NanoLund’s researchers access to these tools as well as to train them in their usage.

LOCAL FACILITIES
NanoLund’s interdisciplinary environment spans the departments of physics, chemistry, biology, medicine, and electrical engineering at Lund University. Researchers at these departments are involved in groundbreaking methodological developments in areas such as: electrical and optical nanocharacterization, ultra-fast laser spectroscopy, scanning probe microscopy, transmission electron microscopy, synchrotron-based imaging, spectroscopy and scattering, nanosafety, computational quantum chemistry, biocompatible nanoelectrodes, and many-body and transport theory.

MAJOR FACILITIES
Members of NanoLund have access to major cutting-edge characterization facilities both in Lund and worldwide, such as: synchrotron and neutron facilities, advanced electron imaging, ultra-fast laser pulses, radiation from the X-ray to the THz regime, and large-scale computing facilities and networks.
**Education**

NanoLund has a variety of programs that integrate its research efforts with those related to educating students, scientists and the general public.

**UNDERGRADUATE AND MASTER’S LEVEL**

Engineering Nanoscience is a 5-year undergraduate and Master’s degree (civilingenjör) program. Its specialization areas are congruent with our scientific focus areas, ensuring close contact between the students and our researchers. Since the program’s start in 2003, more than 200 students have graduated.

**PHD STUDENTS**

NanoLund has around 110 PhD students with access to graduate schools in quantum engineering, microscopy, and health-risk research, as well as to support for international research visits. An industry internship program is being built.

**SCIENTISTS**

We regularly arrange seminars and colloquia, including a tutorial series that presents a broad range of nanoscience topics in a format that is accessible to all scientists.

**PUBLIC OUTREACH**

In the past five years we have undertaken more than 175 activities to help educate the public, including visits to schools, popular science articles, teacher training, and public talks, as well as providing exhibits at museums.
"We love hearing from schools and the public, and communicating the fun, fascination and opportunities of nanotechnology"

"We developed the Engineering Nanoscience program to satisfy the growing need from academia and industry for nanoscience competence."

Dr. Maria Messing, Outreach coordinator, NanoLund

Dr. Martin Leijnse, Solid State Physics
Nanovation

The 'nanovation' program at NanoLund works to promote and coordinate our innovation activities related to nanoscience and nanotechnology and to provide a gateway to industry, academia, and the public.

We do this in collaboration with regional bodies, especially Lund University Innovation Systems, providing our members with know-how on intellectual property (IP) and business development issues. We help established industries and small businesses to adopt, develop, and commercialize nanotechnology-based solutions, and facilitate the public’s understanding of the potential of nanoscience and nanotechnology.

Industry Partners and IP
NanoLund has a well-established infrastructure to collect IP (20–30 patents each year) and spin out companies, which enables the translation of innovations in fields such as solid state electronics, illumination, photovoltaics, and life sciences. Industry partners include both our spin-off companies (e.g. QuNano, Sol Voltaics, and GLO) and companies interested in developing new technologies or improving existing ones, such as the multinational TSMC.

“NanoLund offers unique capabilities to bridge the research-to-application gap and to realize cutting-edge nanotechnology applications from nanoscience basic research.”

Dr. Martin Magnusson, Solid State Physics

Nanovation Gateway
We are here to help. Contact us if you are:

- **An established industry** seeking research collaboration on a specific problem
- **A small business** seeking to expand into a new technology
- **A nanotech company** looking for new cooperation partners
- **A public body** interested in nanotechnology opportunities
- **Simply curious** about applied nanotechnology and nanoscience
NanoLund receives about 180 MSEK in external funding annually 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 standards.

“The high quality and breadth of our research attracts interest and financial support from a wide range of national and international funders, which in turn enables us to continuously develop and enhance the unique capabilities of our nanoscience research environment.”
NanoLund – at the Forefront of Nanoscience

7 ERC Awardees
Coordinator for 6 EU projects

Current numbers

- 26 Contributing divisions
- 61 Faculty Members
- 33% Women
- 110 PhD students
- 180 MSEK Funding

Staff
- 2010: 166
- 2015: 266

PhD students
- 2010: 110
- 2015: 272

Faculty of Medicine
- 2010: 10%
- 2015: 272

Faculty of Natural Sciences
- 2010: 35%
- 2015: 249

Faculty of Engineering
- 2010: 55%
- 2015: 217
“I chose NanoLund for my postdoc because of its interdisciplinary research environment and top-level facilities. I very much enjoyed the free exchange of scientific ideas and opinions at NanoLund, and being trusted to manage different, and sometimes risky, projects that have helped me develop my skills and knowledge significantly.”

Dr. Gaëlle Piret, postdoc 2011–2013 now at Clinatec laboratory, Inserm, CEA Leti (Grenoble) and ERC Starting Grant holder

“NanoLund is at the forefront of nanoscience research on an international level.”

Dr. Dan Csontos, PhD 2003, now at Elevate Scientific, formerly an editor with Nature and Nature Physics

“I cherish the collaborative atmosphere at NanoLund, and the friendships I made during my time in Lund.”

Dr. Philip Wu, postdoc 2010-2012, then at Stanford University