NTNU
The Norwegian University of Science and Technology (NTNU) in Trondheim represents academic eminence in technology and the natural sciences as well as in other academic disciplines ranging from the social sciences, the arts, medicine, teacher education, architecture to fine art. Cross-disciplinary cooperation results in innovative breakthroughs and creative solutions with far-reaching social and economic impact.

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Head of the Department:  Professor Asle Sudbø
Deputy Head of the Department:  Professor Randi Holmestad
Associate professor Jon Andreas Støvneng
Head of Administration:  Sylvi Vefsnmo

Departmental Board
Elected members:

Head of Department  Professor Asle Sudbø
Representing the permanent scientific staff  Associate professor Dag Breiby
Representing the temporary scientific staff  Research scientist Lars Erik Walle
Representing the technical/administrative staff  Head Engineer Per Magne Lillebekken
Representing the students of the department  Student Armend Håti
Student Henrik Vikøren
Student Aksel Jan Vestby

Appointed external member:  Research Manager Jostein Mårdalen, SINTEF Petroleum Research
Professor Lisa Lorentzen, NTNU, Department of Mathematical Sciences

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Illustration: NTNU Info/Ole Kristian Øye
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Edited by:  
*Eli Ljøkeløy Monsøy, Trond Henningsen, Peder Kristian Brenne og Asle Sudbø*  

The Annual Report is also available on:  
[www.ntnu.no/fysikk/arsrapporter](http://www.ntnu.no/fysikk/arsrapporter)
THE DEPARTMENT OF PHYSICS

A GLANCE AT 2010

During 2010, the department welcomed three new faculty members, associate professors Ragnvald Mathiesen and Jacob Linder, and professor Ursula Gibson. The three new members of the faculty are in the process of vigorously establishing their own research programs and building up new laboratory facilities. The department is in the process of hiring several new faculty members, presenting a strategic opportunity to reshape its research profile. 21 new PhD students were welcomed to the department during 2010, while 9 PhD students completed and defended their dissertations. The number of PhD students in the department at the end of 2010 counted 69, while the number of postdocs at the end of 2010 counted 23. This totals 92, significantly up from 70 at the end of 2009.

The number of scientific papers published in international peer-reviewed journals has increased considerably since 2005. In 2010, the number reached a total of 173 (Cristin) in so-called Level 1 and Level 2 scientific journals. Of these, 73 were published in Level 2 journals, which count the most. A search in Cristin yields, for the previous 5 years (2005:117/56; 2006:128/45; 2007:125/53; 2008: 149/69; 2009:153/70). These numbers appear to differ (only) slightly from those that appeared in the previous database Frida. The picture is nevertheless quite clear: The scientific output from the department is very strong, and we publish an impressively large proportion of our scientific papers in Level 2 journals.

The number of new projects funded by the Research Council of Norway, has increased somewhat from 2008. The success rate for applications in basic research is low, even for applications receiving excellent reviews. This is mainly due to underfunding of the Free Projects within the Research Council. There is a growing pressure on the scientific staff to provide external funding for their activities. EU continues to increase its strategic importance as a funding agency for most of our activities. The level of external funding has increased in 2010 compared to 2009, from approximately 35MNOK to approximately 40MNOK. While this is encouraging, we have a long way to go if we are to reach the goals set out in the long term strategic plan of the department. That said, it is important to keep in mind that external funding is not a goal in itself, but a means of realizing goals. In a physics department, this can only be to perform high-quality basic research on physical phenomena.

Our department was one out of 10 Norwegian institutes carrying out research in physics, that were evaluated in 2009 by an international evaluation committee. This was done at the request of the Norwegian Research Council (NRC). The committee handed over the report on their findings to the NRC in 2010. In our department 8 groups were evaluated, 2 of which were rated excellent, namely Biophysical and Medical Technology, and Condensed Matter Theory. Returning to the remark in the previous paragraph, the evaluation showed that there was no obvious correlation between the groups that fared best in the evaluation and the groups that had most external funding. A lack of state-of-the-art equipment in several experimental groups was however pointed out by the committee. Some of the weaker groups also need to focus more on phenomena, and less on analytical tools per se.

The quality of the students in the Physics Department continues to be impressive, as evidenced by the student honours having been bestowed upon several of our MSc and PhD students in 2010 (for more details, see the annual report). The Department is also fortunate enough to be able to recruit outstanding students at the BSs, MSc, and PhD level.

In June 2010, the Department of Physics hosted the 22nd CCP2010 – International Conference on Computational Physics. The meeting was held at NTNU, with Alex Hansen heading the organizing committee.

In 2010, Jacob Linder, received the Trond Lykkes Prize for outstanding research from the Royal Norwegian Society of Science and Letters (DKNVS). The prize was presented to Linder by His Majesty King Harlad VI and the preses of the DKNVS, professor Kristian Fossheim, at the 250th anniversary of the Society. See the annual report for further details.

Moreover, in 2010, professor Arne Brataas, was awarded a large grant from the EU 7FP for research on spin-transport and spin-dynamics. Brataas is the coordinator of this project. Receiving such grants contributes significantly to realizing the ambitions and strategic goals of the Department.

Asle Sudbø
Head of Department
STAFF

Head of Department:
Professor Asle Sudbø

Deputy Head of Department:
Professor Randi Holmestad
Associate Professor Jon Andreas Støvneng

PERMANENT STAFF

SCIENTIFIC STAFF:

Professors
Jens O. Andersen, Anne Borg, Arne Brataas, Catharina Davies, Patrick Espy, Jon Otto Fossum, Ursula Gibson, Alex Hansen, Randi Holmestad, Ola Hunderi, Johan S. Høy, Anders Johnsson, Michael Kachelriess, Morten Kildemo, Berit Kjeldstad, Mikael Lindgren, Tore Lindmo, Thor Bernt Melø, Arne Mikkelsen, Jan Myrheim, Kalbe Razi Naqvi, Kåre Olausson, Steinar Raen, Inge Simonsen, Bo-Sture Skagerstam, Irina Sorokina, Bjørn Torger Stokke, Asle Sudbø, Arne Valberg.

Associate Professors
Berit Bungum, Dag W. Breiby, Antonius Helvoort, Jacob Linder, Ragnvald Mathiesen, Jonas Persson, Paweł Sikorski, Marit Sletmoen, Knut Arne Strand, Jon A. Støvneng, Tore H. Løvaas, Erik Wahlstrøm, Turid Worren, Ingjald Øverbø.

Adjunct Professors
Kenneth Dahl Knudsen, Einar Rofstad, Arne Skretting, Roger Sollie, John Walmsley, Tor Wøhni.

TECHNICAL AND ADMINISTRATIVE STAFF:

Head of Administration
Sylvi Vefsø

Administrative staff

Technical staff
Irene Aspli, Astrid Bjørkøy, Ole Tore Buset, Knut R. Gjervan, Oddbjørn Grandum, Tor Jacobsen, Dagfinn Johnsen, Erling Kristiansen, Lise Kvalø, Per Magne Lillebekken, Gjertrud Maurstad, Arne Moholdt, Jon Ramlo, Inge Sandaunet, Daniel Skåre, Bjørn Gunnar Soleim, Bertil O. Staven, Kristin Grendstad Sæterbø.

TEMPORARY STAFF:

Post Doc/Research Scientist
Swarnali Bandopadhyay, Øyvind Borck, Vladislav Dvoyrin, Flemming Ehlers, Song Fei, Davi Fonseca, Askhat Gazizow, Kristin Høydalsvik, Bjørn Skjetne, Heng Li, Magnus Borstad Lilledahl, Ragnvald Mathiesen, Takemasa Makoto, Jerome Maria, Yrr Mørch, Sylvie Lélu, Sergey Ostapchenko, Katarzyna Maria Psonka-Antoncezyk, Santanu Sinha, Ragnhild Sæterli, Per Erik Vullum, Bao-xiang Wang, Lars Erik Walle, Justin Wells, Minli Xie, Min Zhou, Seoung Shan Yan, Chaolin Zha.

Doctoral Students

PROFESSOR EMERITI:

# ACCOUNTS 2010

## GOVERNMENT UNIVERSITY FUNDING (including NTNU strategy projects)

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## PROJECTS FINANCED BY THE RESEARCH COUNCIL OF NORWAY

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## CONTRIBUTION FROM OTHER FINANCIAL SOURCES

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<td>Transport av terapeutiske makromolekyl i tumorvev</td>
<td>Davies Catharina</td>
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<td>Statens Strålevern</td>
<td>Prof II, Tor Wohlin</td>
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Linder’s dissertation received three awards

In 2010 Jacob Linder received not less than three awards for his PhD dissertation. Linder completed his thesis in March 2009, half a year earlier than meant to. His dissertation, “Quantum transport and proximity effects in unconventional superconducting hybrid systems” - supervised by Professor Asle Sudbø – consists of 25 articles, all published in the reputable journal Physical Review.

Linder was first awarded with the I. K. Lykkes Pris for Yngre Forskere 2010 (I.K. Lykkes Prize for Younger Scientists 2010) on March 12. The ceremony took place at the 250 years anniversary for The Royal Norwegian Society for Sciences and Letters. His Majesty King Harald V was present at the ceremony.

On May 20, Linder was awarded the ExxonMobil’s Research Prize 2010 for basic research. The prize is worth NOK 50 000,-

In September Linder received his third prize, this time by The Norwegian Physical Society. Yara’s Birkeland Prize annually awards the best PhD dissertations carried out in Norway. The award includes both physics and chemistry, and is given to each subject every second year.
HIGHLIGHTS FROM THE ACTIVITY

NTNU’s 100 years anniversary

Friday October 8, The Department of Physics celebrated 100 years of education and research in physics in Trondheim. The celebration started with a scientific seminar and ended with a banquet at the Britannia Hotel in central Trondheim.

Besides the scientific part of the program, much of the emphasis during the celebration was put on the proud history that NTH/NTNU has within the field of physical research and education.

In relation to the anniversary The Department of Physics launched the book “Fysikk i Trondheim gjennom 100 år” (“Physics in Trondheim through 100 years”).

The book maps the history; from the beginning in 1910 to the current Department of Physics at NTNU. Central topics to the book are developments connected to education and research. Integrated in the history is honoring of former profiles and pioneers who have contributed to the positive reputation the physics environment in Trondheim has.

The book is edited by Professor Emeritus Per Chr. Hemmer, Professor Emeritus Anders Johnsson, Professor Emeritus Kjell Mork and Professor Emeritus Ivar Svare.
Department of Physics coordinates its first EU project.

Professor Arne Brataas at the Department of Physics heads the coordination of EU’s 7. Framework Program

The prestigious duty as coordinator for a framework program that is in front within the field, makes it possible to conduct advanced basic scientific research with access to the best technological facilities, and cooperation with the most skilled working staff.

The Project, MACALO - Magneto Caloritronics, intends to study heat, charging and spin, and magnetization dynamics in magnetic nano structures.

The project’s duration is three years, budgeted to €3.2 millions. Other cooperating partners are two firms (NanoOSc (SE) and In Silicio (FR)) plus academic partners from Delft, Wurzburg, Twente, CEA Grenoble and Groningen.

Department of Physics international leading

An international committee initiated by The Research Council of Norway has scrutinized the quality of research within the field of physics. Of the 45 research groups studied, two divisions at the Department of Physics are labeled “excellent”; Biophysical and Medical Technology and Condensed Matter Physics.

The committee concludes that the groups have a leading international role within their respective fields, and that they conduct advanced and original research that manages to be published in the most reputable international journals. The strategic work is well planned, the productivity is high, and the activity is relevant for both national and international research.

The intentions with the evaluation are to get a critical study of the research in an international perspective, and to get international feedback on how research in Norway should face future challenges.
RESEARCH

DIVISION OF APPLIED PHYSICS AND DIDACTIC PHYSICS

Staff
Professor Patrick Espy
Professor Ursula Gibson
Professor Robert Hibbins
Professor Morten Kildemo
Professor Berit Kjeldstad
Professor Mikael Lindgren
Professor Inge Simonsen
Professor Irina Sorokina
Assoc. professor Berit Bungum
Assoc. professor Jonas Persson
Assoc. professor Knut Arne Strand
Assoc. professor Turid Warren Reenaas
Adjunct professor Phil Scott

Staff Engineer Daniel Skåre
Post.doc. Maria Jerôme
Post.doc. Yap Seong Shan

Professor emeritus Johannes Falnes
Professor emeritus Ole Johan Løkberg
Assoc. professor emeritus Tore Løvaas
Assoc. professor emeritus Jørgen Løvseth
Professor emeritus R. Svein Sigmond
Professor emeritus Helge Skullerud

Non-tenured staff
Julien Duboisset (Post-doc)
Seoung Shan Yap (Post-doc)

Overview

The Division of Applied Physics and Didactic Physics consists of several research teams carrying out research within the fields of applied optics and laser physics, electron and ion physics, energy, atmospheric and environmental physics, as well as physics education (“didactic physics”).

The applied optics group carries out advanced laser spectroscopy and imaging of molecular systems in biology and materials sciences (Lindgren). The optics group also develops optical instrumentation prototypes in polarimetry (Kildemo, Lindgren) and theoretical modelling of optical properties of materials and surface reliefs (Simonsen). The laser physics group works with femtosecond lasers based on optical fibers (Sorokina).

Energy and environmental physics includes studies of climate processes, including the influence of solar radiation and energetic particles on atmospheric composition, dynamics and ground-UV irradiance (Kjeldstad, Espy, Hibbins), as well as renewable energy sources such as wind and ocean waves (Falnes, Løvseth). Research on new (third generation) solar cell technologies is also carried out (Reenaas).

Studies of interfaces between fluid phases existing in oil and gas reservoirs are performed by light scattering methods (Strand). The model systems and samples from actual gas and oil fields are studied under reservoir conditions (at pressure up to 700 bar and temperature up to 180°C). The studies are performed with the purpose of improving condensate and oil reservoir management and production. In electron and ion physics one studies electrical breakdown in fluids and gases (Løvaas, Sigmond), breakdown in vacuum related to the Compact Linear Collider (CLIC) at CERN (Kildemo), and transport of ionized gases (Skullerud).

Research in physics education (Bungum, Persson) involves research in physics and technology education in schools as well as at university level. The section also co-ordinates the Nordic research network NorSEd, with grants from NordForsk.

For 2010 we have chosen to give a more thorough account of two specific research projects carried out on electromagnetic nanostructures, and particle precipitation and climate research in Antarctica respectively.

Electromagnetic Nanostructures
(Ursula Gibson, Fredrik Martinsen)

Prof. Gibson moved to NTNU from the USA in August of 2010, and has established a laboratory for the fabrication and characterization of restricted dimension materials. We study the electromagnetic response of structures with nanometer dimensions – thin films, nanorods and nanoparticles, primarily for applications in solar energy, but including interests in optical waveguides and magneto-optics. The emphasis is on the development of new solar absorber materials with reduced cost and low toxicity, and the group collaborates extensively with that of Assoc. Prof. Reenaas and others at NTNU.
Present work concentrates on the production of zinc oxide and sulfides, and we expect to bring online an ultra high vacuum system dedicated to these materials by the end of 2011. Recent work on ZnO nanorods demonstrated that the increased surface area of these materials in a p-n heterojunction solar cell can increase the efficiency, as shown in Fig 1. Copper oxides and related materials are of significant interest for future low-cost solar absorbers, and an understanding of the fundamental interface states with materials such as ZnO are being undertaken.

Particle precipitation and climate research in Antarctica (P.J. Espy, M. Daae, R.E. Hibbins)

In the Polar regions, radiation-belt and auroral particles enter the atmosphere and create highly reactive chemical species such as nitric oxide (NO) that catalytically destroy ozone. During winter, atmospheric winds transport these species into the stratosphere where the changes in the ozone, thermal balance and dynamics may affect the lower atmosphere and climate system. As part of an international collaboration between the NTNU Department of Physics, the British Antarctic Survey, the Max-Planck Institute for Solar System Research and the Norwegian Polar Institute, a 250 GHz radiometer observed profiles of ozone and nitric oxide between 30 and 80 km, deep within the Antarctic polar vortex at Troll Station, Antarctica (72°S, 2.5°E). The instrument is now giving us the first time-resolved picture of how naturally occurring high altitude auroral energy enters and affects the atmosphere, and the extent to which the changes it causes couple into the lower atmosphere and climate system.

Initial results show for the first time that even relatively minor particle precipitation events, which occur frequently and throughout the solar cycle, create significant reactive species that subsequently propagate downward into the stratosphere. As can be seen in the top panel of the following figure, an impulsive particle precipitation event began on 22 July. The event was short lived and of only moderate intensity. However, the particle energy caused an immediate ~15 K increase of the temperature at 90 km, which is shown on the second panel of the figure. The event also created changes in the atmospheric chemistry, creating reactive species that catalytically destroyed ozone.
The third panel shows a 30% ozone loss that occurred as the particles created highly reactive, ozone-destroying species such as NO. As shown in the forth panel, the NO and other reactive species created in the particle precipitation event, and their corresponding ozone destruction, are transported downward into the stratosphere where they can continue to affect atmospheric chemistry, circulation and climate.

Fig. 2. Ozone loss occurring during a moderate particle precipitation event over Troll Station, Antarctica. The top panel shows the solar storm reaching the earth on 22 July, while the second panel shows an immediate increase of temperature at 90 km. The third panel shows a 30% ozone loss that occurs as the particles create highly reactive species such as NO, shown in the forth panel, and these species, and their corresponding ozone destruction, are transported downward into the stratosphere.
DIVISION OF BIOPHYSICS AND MEDICAL TECHNOLOGY

**Overview**

The research is presented under the following headings: Medical physics and technology, Biopolymers and bionanotechnology, and Photobiophysics.

**Medical physics and technology**

**Monte Carlo simulation of 6 MV linear accelerator photon beams**  
*S. Saur Almberg, J. Frengen, T. Lindmo*

As a first step towards establishing Monte Carlo (MC) simulation as a tool for studying surface doses in radiotherapy of breast cancer, the essential elements of Elekta linear accelerators have been implemented in the BEAMnrc MC code, with dose calculations performed by the DOSXYZnrc code. Relevant parts of the linear accelerator, such as electron beam target, primary collimator, flattening filter, backscatter plate, multi-leaf collimator, backup collimator, and main collimator, were implemented using appropriate component modules of the BEAMnrc code. In MC simulation of linear accelerators using this code, the electron energy and the electron radial intensity (width of the electron beam incident on the linac target) have to be adjusted by the user such that both parameters are in accordance with the actual linear accelerator. For this purpose depth-dose and cross-field dose profiles in a 60 x 60 x 30 cm³ water phantom were simulated by MC and compared to corresponding dose measurements obtained by the use of an ionization chamber. The incident electron energy of the linac was determined by matching of simulated and measured depth dose profiles for the field size 5 x 5 cm² (see Fig. 1). Width of the electron beam incident on the linac target was estimated by comparing simulated and measured crossline dose profiles of a 40 x 40 cm² field obtained at 1.5 and 10 cm depth (Fig. 2).

![Fig. 1. Measured (ionization chamber) and MC calculated depth doses for optimal electron energy (6.5 MeV). Field size: 5 x 5 cm², source–surface distance (SSD): 90 cm.](image1)

![Fig. 2. Measured and calculated cross-profiles for a 40 x 40 cm² field. The profiles were calculated using 6.5 MeV electrons and radial intensity distribution (standard deviation of a Gaussian distribution) equal to 0.4 mm and 0.8 mm in the inline and crossline directions, respectively.](image2)
Delivery of nanoparticles in tumour tissue and cells
(C. de Lange Davies, N. Reitan, S. Lelu, Y. Hansen, M. Afadzi, S. Eggen, S. Hak, H. Hektoen, Z. Garaiova, B. Staley)
Nanomedicine such as liposomes, nanoemulsion, polymers or proteins carrying drugs are promising cancer therapeutic agents. Due to the leaky blood vessels in tumour tissue, there is a higher accumulation of the therapeutic agent in tumour tissue than in normal tissue. However, the tumour uptake is low and the distribution heterogeneous. The aim of our research is to study the mechanism and improve the delivery of nanoparticles. In 2010 we have established new tools and instrumentation to strengthen our research and have focused on three main projects:

Characterization of nanoemulsions and their behaviour in cells and in tumours growing in mice. Multifunctional nanoparticles combining contrast agents for imaging and therapeutic agents for therapy have opened new possibilities in cancer therapy. Nanoemulsions containing contrast agents for magnetic resonance imaging and optical probes for laser scanning microscopy have been synthesized and characterized. The nanoemulsion was successfully targeted to endothelial cells in culture. In tumours growing in window chambers microscopy showed accumulations of the targeted nanoemulsion in angiogenic vessel walls in vivo.

Ultrasound mediated drug delivery. Ultrasound may improve the uptake and the distribution of encapsulated drugs in tumours. The exposure parameters (frequency, pulse length, duration, acoustic pressure) to obtain optimal release of drugs from liposomes in solution have been studied and the enhanced release is found to be caused by cavitation. Cavitation is the oscillation of gas bubbles upon exposure to pressure wave and when gas bubbles collapse shock waves and micro-jet streams are formed. We also found that when gas bubbles were added to cells, ultrasound enhanced the cellular uptake of liposomes and dextrans considerably.

Chitosan as a DNA carrier in gene therapy. Chitosans are positively charged polysaccharides which interact with the negatively charged DNA thereby forming nanoparticles. Chitosans with low and high ability to transfect cells were compared, and the cellular uptake, endocytotic pathway and intracellular trafficking were studied. Furthermore photochemical internalization was found to enhance the transfection considerably.

Clinical applications of multiphoton microscopy
(C. de Lange Davies, M. Lilledahl, M. Kildemo, P.G. Ellingsen)
Multiphoton microscopy is an ideal tool for studying many biological molecules. Many important such molecules like collagen, elastin and many lipids can be imaged without any exogenous stains, thereby simplifying in vivo imaging and the potential for clinical applications. Our research aims to identify such clinical applications, develop the necessary analysis tools, and understand the biological relevance of the data to develop multiphoton microscopy as a clinical tool.

Coherent anti-Stokes Raman scattering to study macrophage effect on extracellular matrix. Atherosclerosis is a disease characterized by the development of lipid-rich plaques in the artery walls. The rupture of such plaques is believed to be the primary cause of heart attacks. A high content of macrophages in these plaques is believed to make them more vulnerable to rupture, since the macrophages release enzymes which degrade the supporting collagen matrix. Macrophages are rich in lipids and are therefore easily imaged using Coherent anti-Stokes Raman scattering (CARS) with the lasers tuned to probe the CH\(_2\) stretching vibration. Combining this with imaging of the collagen network using second harmonic generation
(SHG) we are able to study the relationship between the structure of the collagen matrix and the enzymatic effect of the macrophages. This work was a collaboration with the Beckman Laser Institute in the US, as CARS microscopy is not presently available in Norway.

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Structural characterization of cartilage for biomechanical modelling.

Degradation of cartilage is a major health problem in the western world. Osteoarthritis is characterized by changes in the collagen structure of the cartilage leading to painful and debilitating conditions. We have used SHG imaging to quantify the three-dimensional microstructure of the collagen network in cartilage and use this data in finite element modelling of the mechanical response of the tissue.

This will lead to a better understanding of how the changes in the collagen structure changes the mechanical loading in the tissue, providing a better idea of how the disease will progress. As some collagen fibrils and other structural proteins are below the resolution limit of optical microscopy we are combining multiphoton microscopy with Mueller matrix imaging which allows us to quantify the structure of the matrix of molecules which are not obtainable by microscopy.

Biopolymers and bionanotechnology

Biopolymer mesoscale structural organization and interactions

Our research focuses on mesoscale structure formation and interactions within biological macromolecules. This research field includes the internal and collective organisation of biological polymers that is crucial for life, and the knowledge obtained forms a basis for various technological exploitations. We are currently pursuing research topics as e.g. polyelectrolyte complexation, biopolymer multilayers and gels, (1,3)-β-D-glucans and their interactions with polynucleotides, physics of enzymatic mode of action, responsive gels as biospecific signal transducers, and nanoscale studies of toll-like receptors. In addition to classical ensemble averaging techniques, application of single-molecule techniques is a distinctive facet of our approach to tackle core issues within these topics.

In 2010, the high resolution interferometric platform for monitoring changes in optical length within hydrogel materials was extended from the biosensor field to explore characterisation of biopolymer gels in a more general context. Thus, the ionic strength dependence of a covalent crosslinked alginate hydrogel on the fiber before and following impregnation with a commonly used polycation, were reported. The data indicates that the hydrogel swelling as a function of the ionic strength is different for the impregnated hydrogels compared to the non-impregnated ones. Based on such data and also combined with additional approaches, it was suggested that appropriate

Fig. 5. SHG image of a transversal section from the superficial layer of articular cartilage in the knee, illustrating the directionality of the collagen fibers which is a necessary parameter for accurate mechanical modelling of cartilage.
modelling of the material behaviour can lead to determination of the mechanical properties of the outermost layer. This line will be pursued in the following.

In 2010, we reported on application of oligoguluronates as modulators of ionotropic gelation of alginates. The oligoguluronate oligomers are able to be involved in the binding of Ca$^{2+}$, but sufficiently short not to mediate connectivity through their chains. The results indicate that the oligoguluronate oligomers perturb the gelation of alginate differently in the Ca$^{2+}$-limited and non-Ca$^{2+}$-limited regimes. In the calcium limited regime, the oligoguluronate oligomers appear to sequester calcium either by binding to oligoguluronate sequences of the network, or between the free oligoguluronates, yielding an overall net effect of reduced gel strength. In the non-Ca$^{2+}$ limited regime, the experimental data shows increased gel strength in the presence of oligoguluronate blocks.

In 2010, we reported on results obtained here by high-resolution atomic force microscopy of class A and B CpG-DNA that reflect differences in secondary structure of these immunostimulatory, bacterial DNAs. Immunostimulatory CpG-DNA activates the innate immune system by binding to Toll-like receptor 9. Structurally different CpG-containing oligonucleotides trigger a different type of immune response while activating the same receptor. The higher order structure of two different classes of immunostimulatory CpG-DNA class A and class B were investigated. Class A, which contains a partly self-complementary sequence and poly-G ends, forms duplexes and nanoparticles in salt solution, while class B, which does not contain these features and is purely linear, does not form a duplex or nanoparticles.

Fig. 6. Schematic illustration of relevant Ca$^{2+}$-induced alginate chain associations for calcium limited and non-calcium limited situation, and effects of adding oligoguluronates in these cases.

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Fig. 7. Force-extension relation for a single DNA molecule obtained using optical tweezers.

Single molecule techniques in bionanotechnology (K. E. Haugstad, M. Sletmoen)

At the most fundamental level, all biological reactions occur via the action of single enzymes, DNA molecules, or RNA molecules. Studying one biological macromolecule at a time can provide clear and often surprising views of these molecules in action. In 2010, optical tweezers allowing 3D nanoscale force measurements with sub picoNewton sensitivity and sub-nanometer spatial resolution were established in the group. This is a new sensitive force probe complementing AFM.

Procedures to obtain the force-extension relation of single DNA strands using dual trap optical tweezers were developed. The DNA-tether was prepared in collaboration with Svein Valla and Rahmi Lale, Dept of Biotechnology, NTNU. Biotin and DIG labelled primers used in PCR allowed generation of toeholds at the ends of dsDNA to bridge anti-DIG and streptavidin coated microspheres. The positions of the microspheres bridged by a dsDNA were controlled by the optical trap. DNA force-extension curves were obtained by moving one of the beads while recording the force acting on the beads. Fitting the extended worm-like chain model to the experimental data (Fig 7, green line) allowed determining the contour length and persistence length of DNA of different lengths (20, 14 or 8 kbp).

Another optical tweezers based study, performed at the Niels Bohr Institute in collaboration with Lene Oddershede and co-workers, published in 2010, concerned optical trapping and manipulation of single quantum dots. Due to their small size and strong luminescence, quantum dots are optimal for single molecule assays where, optimally, the presence of the tracer particle should not dominate the dynamics of the system. The study included tracking of the thermal fluctuations of a DNA tether.
using an individual colloidal quantum dot as marker (Fig 8).

Mucins are large glycoproteins that promote cell survival in different ways. We are using AFM based dynamic force spectroscopy to study the self-interaction abilities of these glycoproteins as a function of their oligosaccharide decoration patterns.

**Bionanotechnology**

(P. Sikorski, F. Mumm, M. Olderøy, M. Xie)

In the bioneralisation project, the main focus in 2010 has been on testing the applicability of developed hydrogel/calcium phosphate composite materials for cell encapsulation and directing differentiation of stem cells. In collaboration with the Technical University of Munich, we have shown that developed composite materials are suitable for encapsulation of stem cells, and more work in this direction is under way. Another development in 2010 was to mineralise alginate gels using the enzyme alkaline phosphatase, which allows for better control of alginate-mineral interactions at close to physiological conditions.

In our research we extensively use NTNU Nanolab, both for characterisation of biomaterials, as well as for development of new nanotechnology based devices for controlled delivery of molecules into living cells. In 2010 we developed a procedure to fabricate large arrays of vertically aligned copper oxide nanowires. These arrays could then be integrated into cell-friendly, lithographically patterned epoxy structures (Fig. 10 top left and right) to be used as substrates for culturing cells. Due to the much smaller diameter of the nanowires compared to the cells, the cells are able to grow on the surface while being impaled by the wires (see Fig. 10 bottom left). We are currently working to show that material attached to the nanowires can in this way be delivered across the cell membrane into the cell.

**Photobiophysics**

Photosynthetic systems and pigments

(H. Li, T.B. Melø, K.R. Naqvi)

The main focus of attention last year was the investigation of photoprotection provided by \( \alpha \)-tocopherol (or closely related molecules) and carotenoids. Four lines of investigation were pursued, all of which have proved to be exceedingly fruitful.

1) Photophysical and photochemical properties of \( \alpha \)-tocopherol and related molecules. We noticed that, notwithstanding the facile occurrence of one-electron oxidation in \( \alpha \)-tocopherol and its acetate (ToH and TOAc, respectively), and despite the remarkable stability, under appropriate conditions,
of the oxidation products (TOH$^+$, TO$^+$ and TOAc$^+$), their spectroscopic characterization was in such an unsatisfactory state as to justify a fresh attempt at acquiring reliable data. A new, model-free method was developed for analyzing time-resolved spectra showing the progress of the reaction TOH + R$^*$ → TO$^+$ + RH, where R$^*$ is a stable free radical. Absorption spectra of the radical cations were determined by combining EPR and optical spectroscopy. Armed with this knowledge, we were able to show that photoexcitation of TOH in polar solvents leads, contrary to what has been assumed for the last two decades, to photoionization as well as dissociation of the hydroxyl bond.

3) Photoprotection of the reaction centre in photosystem II. Can Trolox, a water soluble analogue of α-tocopherol and a scavenger of singlet oxygen ($^1$O$_2$), provide photoprotection, under high irradiance, to isolated photosystem II (PSII) reaction centre (RC)? To answer the question, endogenous production of $^1$O$_2$ was studied in preparations of five-chlorophyll PSII RC (RC5) containing only one β-carotene molecule, which was found, with the help of linear dichroism spectroscopy, to be located in the D1 protein. The photoinduced oxygen consumption in the oxygen electrode, when RC5 and Trolox were mixed, revealed that Trolox was a better $^1$O$_2$ scavenger than histidine and furfuryl alcohol at low concentrations (i.e. < 1 mM). After its incorporation into detergent micelles in unbuffered solutions, Trolox was able to photoprotect the D1 protein, but not the RC5 pigments. These results are discussed and compared with studies dealing with the physiological role of tocopherol molecules as $^1$O$_2$ scavenger in thylakoid membranes of photosynthetic organisms.

4) Photoprotection of the light-harvesting complex LHCII associated with photosystem II. Photophysical studies on LHCII (wild type and several mutants produced through site-directed mutagenesis) were undertaken to shed light on the role played by xanthophylls in photoprotection.
DIVISION OF COMPLEX MATERIALS

**Overview**

The division carries out research within physics of soft and complex materials. The phenomena studied include: Nanostructured surface alloys, clay-containing systems, biopolymers, spontaneous and guided self-assembly of nanoparticles of various kinds, diffusion properties in nanoporous media, anomalous diffusion processes, mechanical properties of rough surfaces, brittle fracture, mechanical properties of granular media, multiphase flow in porous media.

The research comprises the use of experimental methods, computational methods and theoretical methods.

The list of the experimental instruments and facilities situated at the department is long: X-ray photoelectron spectroscopy (XPS); ultraviolet photoelectron spectroscopy (UPS); low energy electron diffraction (LEED); photoemission electron microscopy (PEEM); temperature programmed desorption (TPD) spectroscopy; a range of UHV sample preparation techniques; wide- and small-angle X-ray scattering; static and dynamic light scattering; light microscopy; atomic force microscopy; measurements of dynamic viscoelastic properties of soft materials (rheology); microcalorimetry; thermo-gravimetry; dynamic electro-optic properties of soft materials; circular dichroism; isolation and purification of nanoparticles including biopolymers.

Using computational methods we study various complex phenomena including flow in porous media, fracture and fracture networks.

The theoretical studies are mainly on condensed matter physics and statistical physics. For details, see below under Survey of research activities.

**Survey of research activities**

**Experimental investigations of soft and complex matter: From nano to macro.**

(*J.O. Fossum*)

The research group has during several years focused on basic understanding of problems within soft and complex materials, in particular physical phenomena in soft matter using synthetic nanolayered silicates (clays), as physical complex model systems. Main physical phenomena studied in these systems include flow and diffusion processes, intercalation processes, spontaneous self-organization into liquid crystalline phases in systems of nanoplatelets, and guided self-organization into electro-rheological and magneto-rheological systems with smart material properties. The most important experimental methods used at NTNU include standard microscopy, as well as AFM and STM; rheology in external applied fields (magnetic or electric); visible light scattering; and wide- and small-angle X-ray scattering. Synchrotron X-ray scattering is performed at ESRF in Grenoble, France, LNLS in Sao Paulo, Brazil, PAL in Pohang, South Korea, Max-lab Lund university in Sweden and other sources. Small-angle-neutron-scattering (SANS) studies are performed at IFE, Kjeller. Magnetic mesonance-spectroscopy and -imaging are performed in collaboration with Universidade Federal de Pernambuco, Recife, Brazil. Other important international collaboration is with University Paris7, University Rennes 1 in France, University of Amsterdam, Universidade de Brasilia and other institutions in Brazil.

**Fracture and transport in disordered systems, growth processes, two-phase flow in porous media**

(*A. Hansen*)

Our group study complex phenomena using computational methods. We study two-phase flow in porous media under steady-state conditions, i.e., when the macroscopic flow parameters have stable averages. This state can be described through non-equilibrium thermodynamics. We are exploring this description in collaboration with Professor Signe Kjelstrup at the NTNU Chemistry Department. We are also collaborating with Professor Knut Jørgen Målay at the University of Oslo who does experiments on steady-state flow in two-dimensional model systems.
We have developed a model for film flow in porous media. This allows us to calculate the effective resistive properties of oil-water-rock systems under different flow conditions. This is necessary input for exploration methods using electromagnetic wave reflection from reservoirs.

Our work on brittle fracture continues with a focus on the possible transition between a percolation-like fracture processes on small scales to a fluctuating elastic line process on larger scales. We use numerical models for this work. In particular, we have developed a model that is capable of following a mode I fracture line indefinitely through creating material in front of the fracture line and removing material behind it.

We are studying hydraulic fracture – i.e. the creation of fractures through high pressure – through collaboration with the SINTEF Rock Physics Group.

We continue our work on devising a description of fracture networks using a duality transformation. This gives the possibility of using all the new tools that have been developed over the last years for describing complex networks.

We study the flow in single fractures in collaboration with Dr. Harold Auradou and Laurent Talon at the Université de ParisSud at Orsay (see Research Highlight Section).

**Self-assembly of 2D-nanostructures**  
*(S. Raaen, A. Julukian)*

Surface properties depend on structure and composition. Of particular interest in the present context is how the reactivity of surfaces varies with effective dimension of nanostructures for metal nanostructures which are supported on non-metallic substrates. One example is Pt nanostructures on graphite, as shown in Fig.1.

It has been known for a long time that the properties of catalytic active metals may be dramatically changed by varying the particle size in the range 2 to 10 nm. Still the detailed mechanisms on how this happens are still not understood. Our studies have focused on model systems in which the details of the adsorption and desorption process may be studied. One example is adsorption and desorption of carbon-monoxide from supported Pt nanostructures. The experiments include photoelectron spectroscopy, temperature programmed desorption spectroscopy and scanning electron microscopy. Fig.2 shows data from CO desorption from Pt/graphite. It is observed that the leading edge in the thermal desorption spectra changes with amount of Pt on the graphite surfaces in such a way that lower desorption temperature corresponds to Pt structures of smaller effective dimension.

The effective size of the Pt structures have been correlated to the electrostatic core level shift due to the unit charge that is left on the metal particle in the final state of the photoemission process. The results have been discussed in terms of surface coordination and the electrostatic properties of the supported metal particles.

![Fig.1. Scanning electron microscopy image of Platinum nanostructures on graphite formed by evaporation at room temperature](image1)

![Fig.2. Temperature programmed desorption of CO from Pt/graphite.](image2)
Fig. 3. Pt 4f core level binding energy as a function of amount of Pt on graphite. Smaller particles give larger binding energies.

Diffusion in granular/traffic flows/quantum optics
(Bo-Sture Skagerstam)
We have focused our attention on the large-time statistical properties of granular flows (work done in collaboration with A. Hansen and project/master students). In this study use has been made of properties of stochastic differential equations. Some features of the large-time behavior can be interpreted as anomalous diffusion. We have shown that such an anomalous diffusion can be described in terms of a conventional memory function in contrast to the sometimes used method of fractional derivatives. We have also studied the appearance of anomalous diffusion and solitary waves in some non-linear systems.

In the field of cavity quantum electrodynamics we have studied the Purcell effect for atoms close to superconducting bodies. We have suggested that the low-frequency dielectric properties of superconducting bodies, which to a large extent is poorly understood, can be investigated by means of spontaneous emission of atoms. Deviation from exponential decay at small and large times has also been investigated in great detail mainly in terms of numerical simulations. A quantum-optics derivation of interference effects in a Michelson-Morley setup for general quantum states has been worked out. The research project on the human eye as a quantum-mechanical detector of photons has continued. Various features of a predictive model for the response of the human eye on low intensity (quantum) light have been investigated.

Polymer-nanoparticle systems
(Kenneth D. Knudsen)
The research has been centered on nanostructured soft matter, with an emphasis on polymer-based systems. Recent progress in polymer science has demonstrated that remarkable changes in material properties are achievable by combining polymers with miniature particles, where at least one of the particle dimensions is in the nano-range. In order to elucidate and subsequently modify the nanostructure of these new materials, we rely heavily on various scattering methods, using mainly neutrons and high-intensity x-rays as probes. Via the collaboration with the Institute for Energy Technology (IFE) we have unique access to specialized instrumentation, particularly small-angle neutron scattering. This method is especially useful for the study of soft and light materials, such as polymers, due to the negligible radiation damage and selective interaction for neutrons compared to x-rays. The work in this area is performed mainly together with prof. J.O. Fossum, as well as master and PhD students.

Example of research carried out in 2010
Flow of fluids in single fractures
(Alex Hansen in collaboration with Harold Auradou and Laurent Talon)
The flow of fluids and gases through fracture systems forms an essential ingredient in connection with the extraction of oil from carbonate reservoirs which have so low permeability that this must be done through the fracture systems they contain. The same situation occurs in connection with natural gas extraction from shales. An essential ingredient in understanding such flow in fractures is to find the relation between the permeability of the fractures as a function of their opening.

Fig. 4 shows the color coded topography of a fracture. Darker red means that the fracture is narrow whereas lighter red means that the opening at that point is larger. The grey areas signal that the opening is zero. The topography of fracture surfaces has certain scaling properties that are summarized in the notion of self affinity. The most important consequence of these scaling properties is that the fracture width scales as the length of the fracture to the exponent 0.8. This is irrespective of the material that has fractured as long as it is brittle.
Several studies in the past have reported non-trivial relations between fracture aperture and the measured permeability. For large mean distance between the fracture planes, the permeability is found to scale with the cube of this distance. In this limit, the fracture can be viewed as consisting of two parallel flat walls. But, as soon as the halves are brought closer together, deviations from this cubic law due to the surface roughness become important. In recent years, various theoretical models based on statistical averages, weak disorder perturbation expansions or mean field approximations have been tested to evaluate these deviations. Most of the foregoing developments, however, break down if contact zones exist in the fracture. When the fracture halves are brought even closer, all the fluid is finally forced to pass a single strait --- or bottle neck --- connecting the inlet and the outlet. The permeability of the entire fracture is then controlled by the permeability of the bottle neck. Also here we find a cubic law.

These various regimes are illustrated in Fig. 5 which shows the flow field for different fracture openings. In d -- for large opening, the cubic regime is seen. In a, we are in the bottle neck regime. In b and c, we are in a regime where the self affinity of the fracture plays a significant role. Dark areas in Fig. 5 signify areas of contact between the two opposite fracture surfaces.

In previous studies of the permeability of fracture surfaces, no scaling regime where the permeability is proportional to the fracture opening to some power has been found. The reason for this is that the right length scale measuring the fracture opening has not been identified until now. It turns out that it is the generalization of a bottle neck in one-dimensional fractures. In two dimensions, it can be defined as the path across the sample that has the least average opening.

By using this length scale, we see in Fig. 5 the three scaling regimes clearly, the middle one being the new one. Here the permeability scales as the new length scale to the power 2.25. The two other regimes are the cubic law regimes that act both for very small and very large fracture openings.

DIVISION OF CONDENSED MATTER PHYSICS

Overview

The research activities include topics both in experimental and theoretical condensed matter physics. The members of the division work with a variety of experimental techniques, ranging from optical spectroscopy, scanning tunneling microscopy, transmission electron microscopy, X-ray scattering, diffraction and imaging employing home laboratory- and synchrotron radiation, for studying physical properties of materials and material structures. A large fraction of the research is focused on nanoscale structure studies and the connection to macroscopic physical properties. A brief survey of the research is given. One research project is described in more detail.

Survey of research activities

X-ray scattering

(D.W. Breiby, R.H. Mathiesen, K.Høydalsvik, W. Mirihanage)

The X-ray group is active in several ongoing projects over a wide range of materials, from organic electronics to various functional and structural inorganic oxides and metallic nano- and microstructured materials. In 2010 the group has continued its activities within national and European research projects, such as FME Solar Cells, ColdWear, SUP Improvement, Nasjonal Forskerskole "Nanoteknologi for Mikrosystem", NFR 3D X-ray Coherent Diffraction Imaging of Working Catalyst Nanoparticles, ESA MAP XRMON and FP7 MIntWeld. The group currently has three PhD students and two post docs. The X-ray laboratory has been undergoing substantial upgrades, and presently consists of three set ups, two of which are used for X-ray scattering and diffraction experiments. Late 2010 the group started assembly and construction of the third instrument, dedicated to microradiographic imaging. The laboratory is generic, covering a large variety of experiments ranging from imaging and tomography, via reflectivity and grazing incidence measurements to traditional wide- and small angle X-ray scattering (WAXS/SAXS). A significant part of the experimental activities of the X-ray group is carried out at synchrotron radiation facilities.

Current research activities include:

- Structure-properties relations in soft-condensed matter, mainly conjugated polymers and liquid crystals for organic electronics.
- Raster scanning WAXS and SAXS measurements of thin films and fibres.
- Studies of catalytic nanoparticles ex situ and under working conditions by incoherent and coherent X-ray scattering.
- Micro- and mesoscale transport during unconstrained dendritic growth
- Pattern selection and interfacial instabilities in regular eutectic solidification microstructures
- Microstructure formation and chemical modification in irregular eutectic systems
- Convective-diffusive interaction during non-equilibrium transport in metal solidification processes. Recrystallisation kinetics in ultra-fine grained metals.

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Lars-Erik walle (Post-doc)
Song Fei (Research scientist)
Wakshum M. Tucho (Post-doc)
Chaolin Zha (Post-doc)
Kristin Høydalsvik (Post-doc)
Wajira Mirihanage (Post-doc)
Transmission electron microscopy (TEM)  
The transmission electron microscopy (TEM) research group is active in several projects including nanoscale structural studies and the connection to macroscopic physical properties, within the field of materials physics. The group has 9 PhD students and 2 post-docs, and work in close collaboration with SINTEF through the TEM Gemini centre (see http://www.ntnu.edu/geminicentre/tem).  

In 2010 the TEM Gemini centre was involved in 26 journal publications, and educated 1 PhD student; Ragnhild Sæterli, within studies of electronic structures. The main objective of the TEM group now is to secure funding for new state-of-the-art TEMs to Norway. We continued in 2010, together with the TEM environment at UiO, to work for a nationally coordinated investment plan in the Research Council’s large scale infrastructure program. Within this initiative we hope to get a probe aberration corrected TEM to Trondheim.

The group has for many years worked with SINTEF and Hydro on alloy development and nucleation of precipitates in aluminum alloys, including structure determination of metastable hardening phases by combining experiments (high resolution TEM, scanning TEM, quantitative diffraction and atom probe) and modeling (density functional theory). In 2010 we started a bilateral project with Japan within these topics. In addition, there is a broad range of research activity on other materials, with a common emphasis on nano/micro understanding of properties and advanced microscopy techniques. Examples are:

- Multicrystalline silicon solar cell materials-defects and impurity influence on efficiency
- Electronic structure of thermoelectric materials
- Functional perovskite materials - ferroelectric thin films and nanorods
- Nanoparticles and support in catalyst materials – electron tomography and other advanced techniques
- High temperature corrosion in steels
- Nanowires of III-V semiconductors
- Intermediate band solar cell materials
- Aluminum surface properties related to corrosion
- High quality TEM sample preparation - tripod polishing

Scanning tunnelling microscopy  
(E. Wahlström, Justin Wells, Fei Song, Chaolin Zha, Lars-Erik Walle, A. Borg,)  
The scanning tunnelling microscopy group has two major lines of research activities primarily based on the scanning tunnelling microscopy instruments in the department, namely nanomagnetics and surface science. There are two ultra high vacuum STM's operated by the group, one with sources and electron energy analyser for UPS/XPS analysis. In addition to this two home built scanning probe microscopes have been developed and are currently operational.

Surface science  
During 2010 the surface science activities have included investigations of oxidation and reduction behaviour of Pd-based single crystal alloy surfaces, an activity run in close collaboration with Department of Chemical Engineering (Prof. H. J. Venvik) at NTNU. Another main topic has been to understand the adsorption behaviour and interaction of selected adsorbates with ordered TiO₂ surfaces. Our studies have included scanning tunnelling microscopy (STM) and high-resolution photoelectron spectroscopy (HRPES) experiments as well as ordinary and spin polarised Angle resolved ultraphot-electron spectroscopy (ARUPS). The HRPES studies are performed at MAX-lab, the Swedish National Synchrotron Facility in Lund, in collaboration with groups at Lund University and Uppsala University. The experimental work is complemented with density functional theory calculations performed both at NTNU and abroad. Specific projects have been:

- Oxidation and reduction of (100)-oriented single crystal surfaces of PdAg and PdCu
• Adsorption of water and gold at anatase and rutile surfaces
• Formation of thin TiO$_2$ films by chemical vapour deposition
• Angle resolved/ spin polarised angle resolved photoemission studies of Bi(441) and graphene/SiC surface.

Experimental Nanomagnetics
The research on nanomagnetics is dedicated to understanding the physics of magnetic structures at the nanoscale. In particular STM-based transport measurements are utilised to understand how charge and spin currents within materials interplay with the magnetisation of materials. A main line of research is performed in conjunction with the Department of Electronics and Telecommunications (Prof. T. Tybell) to study functional metal oxides. The specific activities are during the last year has been performed mainly along these lines:

- Nanostructuring and magnetic properties of La$_{1-x}$Sr$_x$MnO$_3$
- Model systems (Fe and Bi on graphite) for fundamental studies through laterally resolved point contact studies of interface resistance.
- Set up of FMR characterisation (utilising EPR and waveguide set-up)

Research example: Electronic structure of functional oxides studied by electron energy loss spectroscopy
Transmission Electron Microscope (TEM) is a powerful imaging tool. In addition, the local electronic structure of materials can be studied using Electron Energy Loss Spectroscopy (EELS). Being able to study the electronic structure with high spatial and spectral resolution is crucial for the understanding of functional properties at the nm-scale. In 2010 we used EELS combined with structure simulation for the detailed study of the electronic structure of perovskites in order to get more information about their functional properties.

Modified multiferroic BiFeO$_3$ systems[1];
The multiferroic perovskite bismuth ferrite BiFeO$_3$ and the related isostructural compounds Bi$_{0.8}$La$_{0.2}$FeO$_3$ and BiFe$_{0.7}$Mn$_{0.3}$O$_3$ were investigated through experiments and modelling. Using EELS the oxygen $K$ edge, i.e., the unoccupied O $p$ density of states, is probed. As these states participate in covalent bonding with both Bi and Fe states, insight into the bonding in the materials is obtained. By substituting on both cation sites, it is possible to connect features in the spectrum to chemical bonds to the cations. We compare the experimental results of substituted and unsubstituted BiFeO$_3$ and apply a multiple-scattering approach as well as density functional theory to interpret the differences in terms of changes in electronic structure and density of states. Specifically, we show that although mainly ionic, both Bi-O and Fe-O bonds have some covalent character, and that Mn substitution on Fe sites is found to alter the Bi-O bonds and reduce the anisotropy of the system. Upon introduction of La on Bi sites, the covalent character of the material is reduced and the ionic interaction increases as the La-O bond is higher in energy and mediated through other cation orbitals La $d$ orbitals than the Bi-O bond Bi $p$ orbitals. Also, La substitution is found to influence the Fe electronic structure, showing that the $A$ and $B$ site cations are more coupled than commonly recognized. Thus, we use the electronic structure to confirm that $B$ site cation substitution can influence the ferroelectricity, which is usually almost exclusively attributed to $A$ site cation anisotropy.

Thin film ferroelectrics[2];
For ferroelectric materials, the evolution of the order parameter close to an interface is important to understand regarding the stability of the ferroelectric phase, and how to optimize devices taking advantage of the polarization at the interface. We employ EELS in scanning transmission electron microscopy to compare the electronic and structural properties in both bulk and interface regions of epitaxial PbTiO$_3$ thin films grown on SrTiO$_3$ substrates. At the interface, changes in EELS spectra of the Ti-$L_{3,2}$ and O-$K$ edges, as compared to the bulk of the thin film, reveal a reduction in the hybridization of Ti $3d$ and Pb $6p$ states with O $2p$, and thus tetragonal distortion of the TiO$_6$ octahedron. Real-space multiple-scattering calculations of the O-$K$ edge support the experimental results. Moreover, the analysis of the Ti-valence reveals that the change is gradual over ~2–3 nm. The data implies a decreasing ferroelectric order parameter over ~2–3 nm close to the PbTiO$_3$ SrTiO$_3$ interface with a nonzero value at the interface with an additional screening of the polarization over ~1–2 nm into the SrTiO$_3$ substrate from the Ti atoms.

The work has been done in the TEM Gemini Centre by PhD students Ragnhild Satterli and Espen Eberg. Supervisors in Dept of Physics were Ton van Helvoort and Randi Holmestad. Collaborators at NTNU were Tor Grande, Mari-Ann Einarsrud, Sverre M. Selbach and Thomas Tybell. Other collaborators were Ponniah Ravindran at UiO and Takahashi R., Gass M., Mendis B., Bleloch A at SuperSTEM Facility in Daresbury UK.
Figure 1. Experimental and calculated electron loss near edge structure (ELNES) of the oxygen K edge in pure BiFeO$_3$, together with calculated density of states (DOS) for the different orbitals involved. Details in the fine structure relates to changes in bonding. More details are given in [1].

Figure 2. ELNES of the oxygen K edge in PbTiO$_3$ thin film, experimentally for different positions within the thin film and simulated for different $c$-parameters, together with calculated density of states (DOS) [2]. ELNES details can be related to the band structure and change in the order parameter. More details are given in [2].

References:

DIVISION OF THEORETICAL PHYSICS

Overview

The research is mainly carried out within the broad fields of condensed matter physics, statistical physics, quantum physics, and astroparticle physics. These contain several subfields with a large variety of topics for research. An overview is given below.

Survey of research activities and examples of research carried out in 2010

Transport of spin and charge in nanostructures
(A. Brataas, A. Qaiumzadeh, H. Haugen, K. Hals, S. Sadjina, A. Kapelrud)

Understanding nanostructures requires a combination of expertise in different fields by integrating semiconductors and normal metals with magnetic and superconducting materials. Our group explores spin and charge flow in such nanostructures. We aim to develop improved theoretical methods for describing transport phenomena and other physical effects, and use these methods to increase our understanding of experiments. We study the properties of novel systems, pure or hybrid, containing ferromagnets, normal metals, semiconductors, and superconductors. Among our current projects are 1) current induced dynamics in ferromagnets and antiferromagnets, 2) spin flow into superconductors, 3) transport in normal and magnetic semiconductors, 4) fluctuations and dissipation in ferromagnets. We published 10 papers in 2010, among which two in Physical Review Letters, one in EPL, six in Physical Review B, and one in Solid State Communications. Our paper "Effective Magnetic Monopoles and Universal Conductance Fluctuations" in Phys. Rev. Lett. was highlighted in Physics as well as chosen as Editor's suggestion.

Quantum transport in systems with multiple broken symmetries
(J. Linder, A. Sudbø)

During 2010 we published 9 papers in Physical Review B, 1 paper in Physical Review A, and 1 paper in Physical Review Letters. Two of the papers published in Physical Review B were Rapid Communications. In addition, two of the papers were chosen as Editors' Suggestions. The primary research focus has been to explore novel effects pertaining to quantum transport in hybrid systems featuring multiple broken symmetries. A main goal in this context is to find ways to exert experimental control over the generation, manipulation, and detection of spin- and charge-currents. This is interesting both from a fundamental physics point of view and in terms of possible applications in nanotechnological structures. In particular, the topics of research in the above publications include 1) topological insulators and Majorana fermions, 2) triplet supercurrents and proximity effects in ferromagnet/superconductor hybrids, 3) odd-frequency pairing in graphene, 4) phase-separation in Bose-Fermi mixtures, and 5) unconventional superconductivity induced by spin-active interfaces.

Fig. 1. The model employed for a Josephson junction with a ferromagnetic Heusler Cu₂MnAl barrier. The junction width is L, and we take into account a canted magnetization texture near the interfaces with misalignment angles relative to the bulk
magnetization. These spin-active zones generate a long-range supercurrent.

The research highlights from the above publications include the prediction of Majorana fermions generated at the interface between a topological insulator and a hybrid structure consisting of a ferromagnet/superconductor bilayer. We also demonstrated how spin-active interfaces may induce a crossover from conventional BCS superconducting correlations to exotic odd-frequency correlations at a critical interface resistance. In addition, we have developed a model for a recent experiment reporting a long-range triplet supercurrent in a ferromagnetic Josephson junction (see Fig. 1), and explain this result in terms of conversion from singlet to triplet Cooper pairs by canted magnetization textures at the interface regions.

High-Energy Astrophysics
(K. Dolag, M. Kachelriess, A. Neronov, S. Ostapchenko, R. Tomas)
High energy particles interacting with the extragalactic photon background initiate electromagnetic pair cascades. We used data published in 2010 by the Fermi-LAT satellite to derive several constraints on ultrahigh energy cosmic ray models, the flux of cosmogenic neutrinos, and the extragalactic magnetic field. In the former case, we used the diffuse isotropic gamma radiation measured by Fermi-LAT to show that cosmogenic neutrino fluxes are only marginally detectable by existing and currently planned neutrino experiments. In the latter case, we showed that the non-observation of the TeV blazar 1ES 0229+200 by Fermi-LAT requires that the extragalactic magnetic field is stronger than about $5 \times 10^{-15}$ G in at least 60% of space. Thus the (non-)observation of GeV extensions around TeV blazars probes the magnetic fields in voids and puts strong constraints on the origin of extragalactic magnetic fields, favoring its primordial origin in the early universe. An example of the influence of extragalactic magnetic fields on the appearance of TeV blazars, i.e., active galactic nuclei emitting beamed high-energy photons, is shown in Fig. 2. As the strength of the extragalactic magnetic field increases, the image of the blazar acquires an asymmetric halo. While the observation of such halos would lead to an estimate of the field-strength, missing halos were used by us to derive lower limits on the field.

Cosmic ray physics
(M. Kachelriess, G. Giacinti, S. Ostapchenko, D. Semikoz, G. Sigl)
Several works studying the propagation of high energy cosmic rays in the Milky Way and their interactions in the atmosphere were performed. In the latter case, a treatment of nonlinear effects in high energy hadronic interactions based on Reggeon field theory was developed, using a complete all-order resummation of enhanced (Pomeron-Pomeron interaction) diagrams. The developed methods and results were used to develop a new Monte Carlo generator (QGSJET-II model) for hadronic interactions, with numerous potential applications in cosmic ray and collider physics.

Dark Matter
(V. Berezinsky, V. Dokuchaev, Yu. Eroshenko, M. Kachelriess, M. Aa. Solberg)
We concluded our studies of the small-scale clustering of dark matter. In particular, we developed a formalism describing the formation of superdense clumps which can be produced by spiky features in the spectrum of inflationary perturbations and by cosmological phase transitions. The theoretically most interesting property of such clumps is that their evolution can lead to a “gravithermal catastrophe”, similar to the one known from the evolution of stellar clusters.

Multi-Higgs models with additional symmetries
(K. Olaussen, P. Osland, M. Aa. Solberg)
The Higgs particle is the missing piece of the Standard Model of Particle Physics. It is somewhat
of a bête noir within the model, but no convincing alternatives have been found. Higgs particles are more likely to exist in many variants (as particles of a multi-Higgs model) than not at all. Since multi-Higgs models are plagued with a large number of free parameters one tries to impose some organization or symmetry principle to reduce their number. We have proposed and analyzed one possible symmetry, implying that Higgs particles will occur in (weakly broken) SO(3) multiplets, similar to the states of a(n almost) rotation symmetric system.

Very-High-Precision numerical solutions of some Schrödinger type eigenvalue equations

(A. Mushtaq, A. Noreen, K. Olaussen, I. Øverbø)

We have developed, analyzed, and implemented numerical algorithms for solving some Schrödinger equation eigenvalue problems to almost ridiculous high precision (from thousands up to more than one million decimals). As one example (see Fig. 3) we computed the lowest even and odd eigenvalues of the double well potential,

\[-s^2 \psi'' + (x^2 - 1)^2 \psi = \varepsilon \psi,\]

for \(s = 1/50000\). In this case one may use the WKB-approximation to show that the states are degenerate to 28954 decimals. We computed each eigenvalue to a little more than 30000 decimals before taking the difference, and found complete agreement with a 10th order WKB calculation (which however only gives 48 decimals relative accuracy). The method currently works for a large class of problems which can be reduced to ordinary differential equations with only a few singular points, but we have good hopes of extending it to genuine two-dimensional equations. Although we know a couple of possible applications, this is currently a solution in search of a problem.

Dielectric properties of ionic fluids

(J. S. Høye)

A quantized ionic fluid or electron gas with radiating electromagnetic interaction has been considered by utilizing the path integral formalism. With this approach the quantized problem can be regarded as a polymer problem in four dimensions. Thus the quantum mechanical problem can be regarded as a problem where methods developed in classical statistical mechanics can be applied. This includes the situation with time-dependent interactions. In the latter case one finds that current-current correlations are needed besides density-density correlations. With this one finds that the ionic fluid is equivalent to a dielectric one with a non-local dielectric constant. If one lets the ionic fluid represent the free electrons of a metal, one can obtain the Casimir force between metallic plates. It is shown that there is no zero frequency transverse electric mode that would contribute for non-zero temperatures. This issue has been heavily debated for many years in the Casimir research community. Further the influence of radiation corrections has been included in the Hartree-Fock and density functional theory evaluations of molecular energies.

Critical properties of fluids

(J. S. Høye, E. Lomba)

By previous investigation by one of us the critical properties of the unified HRT (hierarchical reference theory) and SCOZA (self-consistent Ornstein-Zernike theory) were obtained on the basis of certain assumptions. This led to simple numbers for the critical indices. In standard notation they were \(\alpha = 0\), \(\beta = 1/3\), \(\delta = 5\), \(\gamma = 4/3\), \(\eta = 0\), and \(\nu = 2/3\). It was further argued that, based upon graph expansion arguments, it was not ruled out that these indices except for logarithmic type corrections might be the exact ones for fluids, lattice gases, and the Ising model. By the present investigation the critical properties for the unified
problem is investigated by further analytic work and numerical evaluations. It is noted that in the critical region the HRT part of the problem dominates, so the SCOZA part can be neglected in this respect. From earlier extensive numerical work by others it is well known that for the HRT, values close to 1/3 have been obtained for the index \( \beta \) depending slightly upon the precise equations used. With given index \( \delta = 5 \) the other indices then follow by the usual scaling relations.

**Surface structure and reactivity**

(Ø. Borck, K. Nigussa, K. L. Nielsen, J. A. Støvneng)

Density functional theory (DFT) is used to investigate the geometry and electronic structure of various crystal surfaces, as well as their reactions with atoms and small molecules. Of particular interest are chromium oxide, with numerous applications within catalysis and corrosion resistance, nickel titanium “shape memory” alloys, with applications within biomedicine, and cerium platinum surface alloys. For the NiTi system, the DFT calculations illustrate how doping with potassium has a tendency to deplete nickel atoms from the surface and enhance the formation of a protective layer of titanium dioxide, thereby promoting the biofunctionality of the material (see Fig. 4). The nickel titanium work has been published in Physical Review B. Parts of the chromium oxide work has been accepted for publication in Corrosion Science.

**QCD Phase Diagram**

(J. O. Andersen, R. Khan, L. T. Kyllingstad, L. E. Leganger)

Quantum chromodynamics is generally accepted as the theory that describes the strong interactions among the quarks and gluons. Due to a remarkable property of nonabelian gauge theories called confinement, free quarks are never observed. All quarks are confined inside the hadrons. Hadrons are the bound states of a quark and an antiquark (e.g. pions and kaons), and three quarks (e.g. protons and neutrons). If hadronic matter is heated, it is expected to undergo a phase transition to a new state of matter called the quark-gluon plasma. In this state of matter, the quarks and gluons are no longer confined but are free to move around large distances. The quark-gluon plasma is similar to an ordinary electromagnetic plasma, but is more complicated due to the nonabelian aspects of QCD. The quark-gluon plasma existed in the early universe and so understanding its properties is essential in cosmology. In order to study the properties of the plasma, large experimental efforts at CERN and Brookhaven are made to create it in heavy-ion collisions. Strongly interacting matter also behaves in a highly nontrivial manner if one increases the density. If the density becomes sufficiently high, there is a phase transition to quark matter, which might be in color superconducting state if the temperature is low enough and the baryon density is high enough. This part of the phase diagram (see Fig. 5) is relevant in astrophysics as compact stars are the only known candidate for containing quark matter in its interior.

![Fig. 4. Adsorption of O₂ on a K-doped B19' NiTi (010) surface. (Top view; O – red, K – green, Ti – blue, Ni – white.)](image)

![Fig. 5. QCD phase diagram as function of baryon chemical potential and temperature.](image)

We are currently carrying out research to determine the thermodynamic properties of the quark-gluon plasma and various phases of dense matter. In particular, we have been using hard-thermal-loop perturbation theory to thermal QCD and studied the possibility for Bose-Einstein condensation of diquarks in two-color QCD. This is a part of the large efforts being made to obtain a quantitative understanding of the properties of strongly interacting matter at finite temperature and density. The group published four papers and four conference proceedings in 2010, among others one in Physical Review Letters.
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Afadzi, Mercy; Davies, Catharina De Lange; Hansen, Yingye Hofstad; Johansen, Tonni Franke; Másoy, Svein-Erik; Angelsen, Bjørn Atle J.. Ultrasound stimulated release of liposomal calcien. 2010 IEEE International Ultrasonics Symposium (IUS); 2010-10-11 - 2010-10-14

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(Total 14)

Brataas, Arne

Bungum, Berit
En case fra vitenskapshistorien: Nikola Tesla. Videreutdanningskurs, Teknologi og forskningslære; 2010-03-23 - 2010-03-24

Bungum, Berit
Hva kan plastforming bidra med i teknologiprosjekter?. Nettverkssamling for Teknologi og Forskningslære; 2010-09-16

Bungum, Berit
Lærebøker i naturfag fra lærebokforfatterens perspektiv. Masteremne i naturfagdidaktikk; 2010-10-27

Bungum, Berit; Bjorkum, Per Arne
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Bungum, Berit; Jørgensen, Eva Celine
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Espy, Patrick Joseph
Vulkansk aske i atmosfæren. Kunnskapsbyen; 2010-09-16

Falnes, Johannes
Havbølgjeenergi: potensial og status. Opning av Kompetansesenter for havenergi, Runde Miljøsenter; 2010-10-28 - 2010-10-28

Forre, Bernt; Olaussen, Kåre; Løvaas, Tore Høe; Nordam, Tor
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Gibson, Ursula
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Leganger, Lars Erlend
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Linder, Jacob; Leganger, Lars Erlend
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Sorokina, Irina T
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Brataas, Arne; Normannsen, Solvi Waterloo

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Letnes, Paul Anton; Nerbo, Ingar Stian; Aas, Lars Martin Sandvik; Ellingsen, Pål Gunnar; Kildemo, Morten

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Vill fange sol billig. Adresseavisen 2010-11-02

Sikorski, Pawel
Gullmus hjelper forskarar å lage lengre nanotrådar. NRK Nett 2010-12-17
NTNU

Sikorski, Pawel; Mumm, Florian
Sea mouse boost for nanowire-makers. New Scientist magazine 2010-08-07
COOPERATING INSTITUTIONS

EUROPE

Andersen, J.O.:
* Frankfurt University, FIAS, Germany (Nan Su and Michael Strickland)
* Gettysburg college (Michael Strickland)

Borg, A.:
* Department of Physics and Materials Science, Uppsala University, Uppsala, Sweden (docent A. Sandell)
* Department of Synchrotron Radiation Physics, Lund University, Sweden (prof. J. N. Andersen and docent E. Lundgren).
* Department of Chemistry (Lund University, Sweden (prof. P. Uvdal)

Brataas, A.:
* TU Delft, Kavli Institute of Nanoscience (Gerrit E. W. Bauer) (Nederland)
* University of Konstanze, Department of Physics (Wolfgang Belzig) (Tyskland)

Breiby, D.W.:
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* Technical University of Denmark, Denmark (Dr. J.W. Andreassen)
* Swiss Light Source, Paul Scherrer Institute, Switzerland (Dr. O. Bunk, Dr. A. Diaz)
* Physik Department, Technical University of Munich, Germany (Prof. C.M. Papadakis)
* Max Planck Institut für Polymerforschung, Mainz, Germany (Prof. K. Müllén, Dr. W. Pisula)
* Imperial College, UK (lecturer N. Stingelin)
* Univ. Le Mans / CNRS, France (A. Gibaud)

Bungum, B.:
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* University of Copenhagen, Department of Science Education, Denmark (Dr. Jens Dolin)
* University of Helsinki, The Research Centre for Mathematics and Science Education, Finland (Prof. Jari Lavonen)
* University of Iceland, Science Education Research Group, School of Education, Iceland (Prof. Allyson Macdonald)

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* Faculty of Medicine and Human Science, University of Manchester, UK (Lecturer Alain Pluen)
* University of Leeds, School of Chemistry, (John Plane), Leeds, UK.

Espy, P.:
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* The Max Planck Institute for Solar System Research, Department of Planets and Comets (Paul Hartogh), Katlenburg-Lindau, Germany.
* Department of Meteorology, Stockholm University (J. Stegman), Stockholm, Sweden.
* University of Leeds, School of Chemistry, (John Plane), Leeds, UK.

Fossum, J.O.:
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* CEA-Saclay, France (Dr. Elisabeth Bouchaud)
* Ecole Normal Superieure, Paris, France (Prof. Daniel Bonn)
* University of Amsterdam, Netherlands (Prof. Daniel Bonn)
* Universite de Rennes 1: Geosciences Rennes, France (Prof. Yves Meheust)
* Maxlab Lund University, Sweden (Dr. Tomas Plivelic)

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* University of Loughborough, United Kingdom (R. Smith)

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* Université Louis Pasteur, Strasbourg, France (Schmittbuhl)
* Université de Rennes I, Rennes, France (Bideau, Davy)
* Université Paris-Sud, Orsay, France (Arradou and Talon).

van Helvoort, A.T.J.
* CNRS-LPN, Marcoussis, France (G. Patriarche).
* Institut til Festkoerperphysik, Universität Bremen, Bremen, Germany (A. Rosenauer)
Holnestad, R.:
* Rouen University /CNRS, France (W. Lefebvre)
* University of Milano Bicocca, Italy (S. Binetti)
* Denmark Technical University, Denmark (R. Dunin-Borkowski/ C. Boothroyd)
* University of Poltier, France (J. Pacaud)
* Helmholtz Centre Berlin, Germany (J. Banhart)
* SuperSTEM, Daresbury, England (A. Bleloch)

Høye, J.S.:
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Kachelriess, M.:
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* Institute for Nuclear Research, Moscow, Russia (V. Berezinsky, V. Dokuchaev, Yu. Eroshenko, D. Semikoz)
* Laboratori Nazionali del Gran Sasso, Assergi, Italy (V. Berezinsky)
* MPI für Astrophysik, Garching, Germany (K. Dolag)
* University Hamburg, Germany (R. Tomas)
* ISDC Data Center for Astrophysics, University of Geneva (A. Neronov)

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Linder, J.:
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* NORDITA, Sweden (A. Black-Schaffer)

Lindgren, M.:
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* Kungliga Tekniska Högskolan, Teoretisk Kjemi, Stockholm (Hans Ågren)
* Umeå Universitet, Organisk kemi, Umeå (B. Eliasson)
* Riken, Biophotonics Lab, Wako-shi, Japan (Tamotsu Zako).
* Université Claude Bernard (Lyon1), Laboratoire des Multimatiériaux et Interfaces (Stephane Parola)
* ENS-Lyon (Ecole Normale Superieure), (Chantal Andraud)

Mathiesen, R.:
* University Paul Cezanne - Aix Marseille III, L2MP, France (H.N. Thi, G. Reinhart, B. Billia)
* Catholic University Leuven, Belgium (L. Froyen)
* Techn University Berlin, Germany (F. Garcia-Moreno, A. Greische,)
* ACCESS e.V, Aachen, Germany, (G. Zimmermann, L. Sturtz)
* University College Dublin, Ireland (D. Browne)
* Univ. Leicester, UK (H. Dong, E. Atkinson)
* Univ. Oxford, UK (A. Cocks, N. Marzari, S. Lozano-Perez)
* Tech. Univ. Delft (C. Kleijn, I. Richardson)
* KTH, Sweden (L. Högland, J. Ågren)
* EPFL, Switzerland (J. Dantzig)

Melo, T.B., Naqvi, K. R.:
* ITQB, Universidade Nova de Lisboa, Oeiras, Portugal (E. Melo)
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* Department of Chemistry, Yarmouk University, Irbid, Jordan (Y.A. Yousef)
* Department of Chemistry, Faculty of Science, Mansoura University, New Damietta, Damietta, Egypt (A. El-Agamey)
* Division of Chemistry and Biological Chemistry, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore (R. D. Webster)

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* Linköping University (Per-Olof Holtz) Materials Science
* Universidad Politécnica de Madrid (Antonio Marti) Instituto de Energía Solar – ETSIT
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* Department of Biochemistry, School of Life Sciences, University of Sussex, UK  
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* Bionanotechnology and Nanomedicine Laboratory, University of Copenhagen (Assoc. Prof. Karen Martinez)  
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Sudbø, A.:  
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* New York University, (Andrew D. Kent) (USA)  

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* UFABC, Sào Paulo, Brazil (Prof. Roosevelt Droppa)  
* University of Brasilia, UnB, Brasilia, Brazil (Prof. Geraldo Jose da Silva)  
* Universidade Federal de Campina Grande, UFCG-PB Brazil (Prof. Suedina Silva)  
* PUC Rio de Janeiro Brazil (Prof. Marcio Carvalho)  
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* Case Western Reserve University School of Medicine, Cleveland, Ohio, USA (T A Gerken)

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* University of Toronto (prof. John Wei)
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* Department of physics, University of California at Riverside, USA (prof. C. M. Varma).

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* Pohang Accelerator Laboratory, South Korea (Prof. Do Young Noh)
* Postech Pohang, South Korea (Dr. Kanak Parmar)

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* Cancer Biology Laboratory, Peter Mac Callum Cancer Centre, Melbourne (Robin Anderson)

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* Monash University, Melbourne, Australia (J. Etheridge, M. Weyland, P. Nakashima)

Mathiesen, R,:  
* Univ. Queensland (A.K. Dahle)

Skagerstam, B.S.:  
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NATIONAL COOPERATION

* Naturfagsenteret (Nasjonalt senter for naturfag i opplæringen)  
* NAROM (Nasjonalt senter for romrelatert opplæring)  
* University of Oslo, Physics Education Research Group  
* Hydro Aluminium Research Centre, Sunndalsøra (Jostein Røyset, Oddvin Reiso)
* Department of Chemistry, Biotechnology and Food Science, Norwegian University of Life Sciences, Ås, Norway (Prof. V.G.H. Eijsink)
* Institute for energy technology, Kjeller, Norway (senior scientists Arne Skjeltorp, Geir Helgesen, Kenneth D. Knudsen, Bjørn Hauback, Erik Marstein)
* Division of Biophysics and Medical Technology, Radium Hospital, Oslo (Ø. Brunlad, A. Skretting, D.R. Olsen)
* Statoil Research Centre, Trondheim (F. Antonsen, H. Widereoe, Erling Ryutter)
* University of Oslo (J.M. Leinaas, A. Dahlback, E.G. Flekkøy, K.J. Måløy, Johan Taftø, Øystein Prytz, Ame Olsen, Anette Gunnæs, H. Fjellvåg, O. Nilsen)
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* Optomed (R. Ellingsen, D.R. Hjelme, B. Falch)
* FMC Biopolymers (E. Onsøyen)
* Norwegian Radiation Protection Authority (Bjørn Johnsen, Terje Christensen)
* Tambartun National Resource Center for the Visually Handicapped, Melhus (P. Fosse)
* Centre for Viking and Medieval Studies, University of Oslo
* Finmark University College (Bjørn Tore Esjeholm)
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* Optomed (R. Ellingsen, D.R. Hjelme, B. Falch)
* FMC Biopolymers (E. Onsøyen)
* Norwegian Radiation Protection Authority (Bjørn Johnsen, Terje Christensen)
* Tambartun National Resource Center for the Visually Handicapped, Melhus (P. Fosse)
* Centre for Viking and Medieval Studies, University of Oslo
* Finmark University College (Bjørn Tore Esjeholm)
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* Institute for energy technology, Kjeller, Norway (senior scientists Arne Skjeltorp, Geir Helgesen, Kenneth D. Knudsen, Bjørn Hauback, Erik Marstein)
* Division of Biophysics and Medical Technology, Radium Hospital, Oslo (Ø. Brunlad, A. Skretting, D.R. Olsen)
* Statoil Research Centre, Trondheim (F. Antonsen, H. Widereoe, Erling Ryutter)
* University of Oslo (J.M. Leinaas, A. Dahlback, E.G. Flekkøy, K.J. Måløy, Johan Taftø, Øystein Prytz, Ame Olsen, Anette Gunnaes, H. Fjellvåg, O. Nilsen)
* University of Bergen (J.Stamnes, P. Osland)
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* Tambartun National Resource Center for the Visually Handicapped, Melhus (P. Fosse)
* Centre for Viking and Medieval Studies, University of Oslo
* Finmark University College (Bjørn Tore Esjeholm)
* Numerical Rocks AS, Trondheim (Ramstad, Øren)
* Høgskolen I Sør-Trøndelag, HiST (E. Munkeby)
### EDUCATION

#### SUBJECTS AND STUDENT ATTENDENCE

Some subjects were self-study courses in 2010

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Student Attendance</th>
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<tbody>
<tr>
<td><strong>MSc Technology 1(^{st}) and 2(^{nd}) year</strong></td>
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<tr>
<td>TFY4102 Physics for Product Design Engineering, Earth Sciences and Petroleum Engineering (incl. lab)</td>
<td>134</td>
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<tr>
<td>TFY4104 Physics for Product Design and Manufacturing, Marine Technology (incl. lab)</td>
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<tr>
<td>TFY4106 Physics for Civil and Transport Engineering, Industrial Economics and Technology Management (incl. lab)</td>
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<tr>
<td>TFY4115 Physics for Electronics Engineering, Engineering Cybernetics, Nanotechnology</td>
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<tr>
<td>TFY4120 Physics for Chemical Engineering and Biotechnology, Materials Science and Engineering (incl. lab)</td>
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<tr>
<td>TFY4125 Physics for Computer Science, Communication Technology</td>
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<td>TFY4145 Mechanical Physics (incl. lab)</td>
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<td>TFY4155 Electromagnetism (incl. lab)</td>
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<td>TFY4160 Wave Physics (incl. lab)</td>
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<td>TFY4165 Thermal Physics (incl. lab)</td>
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<td>TFY4215 Introduction to Quantum Physics</td>
<td>98</td>
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<tr>
<td>TFY4335 Nano Life Science</td>
<td>26</td>
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| **MSc Technology 3\(^{rd}\) year** | |
| TFY4170 Physics 2 for Electronics Engineering | 40 |
| TFY4185 Measurement Techniques (incl. lab) | 84 |
| TFY4190 Instrumentation (incl. lab) | 76 |
| TFY4195 Optics (incl. lab) | 79 |
| TFY4205 Quantum Mechanics II | 42 |
| TFY4230 Statistical Physics | 76 |
| TFY4240 Electromagnetic Theory | 63 |
| TFY4250 Quantum Mechanics I | 54 |
| TFY4260 Cell Biology and Cellular Biophysics (incl. lab) | 47 |

<p>| <strong>MSc Technology 4(^{th}) year</strong> | |
| TFY4200 Optics, Advanced Course (incl. lab) | 5 |
| TFY4210 Quantum Theory of Many-Particle Systems | 11 |
| TFY4220 Solid State Physics (incl. lab) | 115 |
| TFY4225 Nuclear and Radiation Physics (incl. lab) | 41 |
| TFY4235 Computational Physics | 22 |
| TFY4245 Solid State Physics, Advanced Course | 13 |
| TFY4255 Materials Physics (incl. lab) | 10 |
| TFY4275 Classical Transport Theory | 6 |
| TFY4280 Signal Processing (incl. lab) | 14 |
| TFY4292 Quantum Optics | 13 |
| TFY4300 Energy and Environmental Physics | 57 |
| TFY4305 Non-linear Dynamics | 7 |
| TFY4310 Molecular Biophysics (incl. lab) | 7 |
| TFY4315 Biophysics of Ionizing Radiation | 5 |</p>
<table>
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<th>Code</th>
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<td>TFY4320</td>
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<td>TFY4340</td>
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<td>TFY4345</td>
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<tr>
<td>TFY485x</td>
<td>Experts in Team, Interdisciplinary Project</td>
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<td><strong>MSc Technology 5th year</strong></td>
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<td>TFY4265</td>
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<td>TFY4900</td>
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<td><strong>PhD</strong></td>
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<td>FY8100</td>
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<td>Magnetic Resonance Imaging</td>
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<td>Advanced Theoretical Physics</td>
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</table>
FY8901  Sensors and Transducers  2
FY8902  Atmospheric Physics and Climate Change  4
FY8904  Computational Physics  6
FY8905  Materials Physics  2
FY8906  Biophysical Micromethods  3
FY8907  Classical Transport Theory  2
FY8908  Quantum Optics  0
THESIS – GRADUATE STUDIES

Master of Science in Technology – Applied Physics and Mathematics

Alnes, Solveig Søvik
Mechanisms of Particle Deposition in a Turbulent Channel Flow
Supervisor: Jon Andreas Støvneng / Nils E. Haugen

Alvestad, Øystein
Exclusive Two-Photon Production of Lepton Pairs in PYTHIA8
Supervisor: Michael Kachelriess / Martin Pohl

Bjornstad, Anders Granskogen
Particle Deposition on a Cylinder in Turbulent Cross Flow
Supervisor: Jon Andreas Støvneng / Nils E. Haugen

Blindheim, Eirik Voje
Experimental Studies of Particle Organization and Rheology of Clay Suspensions
Supervisor: Jon Otto Fossum

Bojesen, Troels Arnfred
Theoretical Investigations of the Tunneling Current in Josephson Junctions made of Single- or Multiband Superconductors
Supervisor: Asle Sudbø

Christoffersen, Ingeborg M.
A Numerical Study of Turbulent Mixing in Coaxial Jets
Supervisor: Jon Andreas Støvneng / Nils E. Haugen

Eidsaa, Marius
Debye Mass to Order $g^{-6}$ for Massless Scalar Phi$^4$ Theory by an Effective Field Theory Approach
Supervisor: Jens Oluf Andersen

Ellingsen, Pål Gunnar
Development of Mueller Matrix Imaging Technique for Characterising Collagen Spatial Orientation in Cartilage: Comparison to Multiphoton Microscopy
Supervisor: Morten Kildemo

Fredriksen, Tonje Dobrowen
Color Coded Velocity Spectrum. A New Method for Quantification of Mitral Regurgitation Using Parallel Beamforming
Supervisor: Marit Sletmoen / Torbjørn Hergum

Grimsmo, Arne Løhre
Open Systems and Measurement in Quantum Optics. The Photodetection Process and Master Equations
Supervisor: Bo-Sture Skagerstam

Haugstad, Kristin Elisabeth
Implementation of Optical Tweezers for Single Molecule Characterisation
Supervisor: Marit Sletmoen

Helgaker, Jan Fredrik
Microstructure and Hardness Evolution During Aging of Two 6xxx Al-Alloys
Supervisor: Randi Holmestad

Hersvik, Kjetil
Oil-Oil Droplet Deformation under DC Electric Field. A Method to Investigate Clay Electrorheology
Supervisor: Jon Otto Fossum

Hilde, Ingeborg Lunby
Image Stabilization for Intraoperative Echocardiography
Supervisor: Catharina Davies / Hans Torp

Hofstad, Kjetil
Design and Construction of a Photoreflectance Setup for the Study of Quantum Dot Intermediate Bands
Supervisor: Morten Kildemo

Jaarvik, Merete
Analysis of CSEM Data Near Salt
Supervisor: Ingve Simonsen / Ketil Hokstad

Mohn, Silje
Implementering av datamodell for simulering av pastebevegelser påvirknå på forventet dosefordeling under behandling med IMRT
Supervisor: Tore Lindmo / Ellen Wasbø

Muggerud, Astrid-Marie Flattum
Electron Microscopy Studies and Microanalysis of Front Contact Interfaces in Silicon Solar Cell Materials
Supervisor: Randi Holmestad / Per Erik Vullum
Oksavik, Odne Andreas  
A New Method for Measurement of Fluid Saturation in Reservoir Core Samples Using Gamma Radiation  
Supervisor: Tore Lindmo / Matts Devik

Revheim, Kari  
Kartlegging av strålefeltet rundt gammakniven  
Supervisor: Tore Lindmo / Jan Heggedal

Rimstad, Eivind  
Sea Ice Fracture Networks  
Supervisor: Alex Hansen

Sigstad, Mats  
Experimental Studies of Temperature Effects on Colloidal Dispersions of Clay Nanoplatelets  
Supervisor: Jon Otto Fossum

Skåring, Øyvind  
Ultrashort Relaxation Dynamics in Laser Excited Semiconductors  
Supervisor: Jon Andreas Støvneng / Trond Brudevoll

Spreemann, Gard  
Topological Quantum Field Theories on a Category of Open and Closed Cobordisms  
Supervisor: Jens Oluf Andersen / Nils Baas

Svanes, Eirik Eik  
The Non-Perturbative Renormalization Group with Applications  
Supervisor: Jens Oluf Andersen

Tveit, Johannes  
TEM Characterization of ZnO Nanostructures to be Utilized in Organic/Inorganic Solar Cells  
Supervisor: Randi Holmestad

Vevatne, Jonas Nesland  
Sea Ice Fracture Networks  
Supervisor: Alex Hansen

Wille, Egil  
Measurement and Logging of Ice Temperatures  
Supervisor: Erik Wahlström / Bernt Førre

Wisting, Håvard Norøm  
MICE EMR Prototype. Efficiency and PMT Calibration  
Supervisor: Michael Kachelriess / Alain Blondel

Yang, Sylvia Xuewei Ma  
Functional Testing of Patients with Achilles Tendon Rupture  
Supervisor: Catharina Davies / Tine Alkjær Eriksen

Ødegård, Martin  
Optimizing Traffic Flow in a New Cellular Automaton Model for City Traffic  
Supervisor: Alex Hansen

Ødegården, Torgeir Bryge  
Oil Release and Transport Mechanisms Due to Wettability Change in a Mixed-Wet 2D Porous Medium  
Supervisor: Alex Hansen / Erik Skjetne

Master of Science in Physics

Bukholm, Ole Magnus  
Interaction-Free Measurement with a Mode-Sensitive Absorber  
Supervisor: Bo-Sture Skagerstam

Eggum, Stein  
Unconventional Goldstone Bosons and Nielsen-Chadha Counting Rule  
Supervisor: Jens Oluf Andersen

Eriksen, Jon Alm  
Overlap Distributions of Random Cantor Sets and their Applications  
Supervisor: Alex Hansen / Bikas Chakrabarti, SAHA

Espe, Bjørnar Ronning  
Material Removal in Wire Sawing of Silicon  
Supervisor: Turid Reenaas / Otto Lohne

Gudmundsen, Magne  
Improved Secret Key Rate in Quantum Key Distribution using highly irregular Low-Density Parity-Check Codes  
Supervisor: Kåre Olaussen

Johnsen, Magnus Berg  
Hypertermisk fremkalt celledød i kreftcellelinejen Jurkat: Computerassistert analyse basert på fluorescensmerking og morfologi  
Supervisor: Thor Bernt Melø

Kleinknecht, Nora  
Planetary Wave Oscillations Observed in Ozone from Troll Station Antarctica  
Supervisor: Patrick Espy
Klemetsen, Lars Erik  
*An Experimental and Numerical Study of the Free Surface Pelton Bucket Flow*  
Supervisor: Jan Myrheim / Torbjørn Nielsen

Lie, Leif Amund  
*Optical Properties of a Thin Film of Coated, Truncated Spheres*  
Supervisor: Ingve Simonsen

Kvalsund, Karsten Arne  
*The Modified Newtonian Dynamics. An Introduction to and Comparison of MOND and CDM*  
Supervisor: Jan Myrheim

Lund, Harald  
*Variation of the Hydroxyl Near Infrared Airglow at Rothera, Antarctica (68°S, 68°W)*  
Supervisor: Patrick Espy

Langseth, Anders  
*Lydhastighet i væsker*  
Supervisor: Ingve Simonsen / Jørn Stenebråten

Salomatova, Olessia V.  
*Growth of Germanium Quantum Dots on Silicon by Pulsed Laser Deposition*  
Supervisor: Turid Reenaas

Sivertsen, Henrik  
*Flow Pattern Visualization*  
Supervisor: Jan Myrheim

---

**Master of Science in Condensed Matter Physics**

Abriha, Tadelle Haddush  
*SEM Microstructure Study and Hardness Evaluation of Al-Mg-Si (Ge) (6XXX) Alloys*  
Supervisor: Randi Holmestad

Aggrey, Eric  
*Synthesis of Anodic Alumina Oxide Template for Growth of Magnetic Nanowires*  
Supervisor: Erik Wahlström

---

**Master of Science in Medical Technology – Biophysics and Medical Physics**

Vallee, Emilie  
Supervisor: Tore Lindmo / Asta Håberg

---

**Master of Science in Science Education**

Sjøvik, Vegard Aas  
*Group Discussions around a Force Platform - A qualitative study of the use of language to reveal and correct pupils' alternative conceptions in mechanics*  
Supervisor: Berit Bungum / Hanne Mehli

Øren, Øystein  
*A Study on the Interaction Between YouTube Videos and Cooperative Learning*  
Supervisor: Berit Bungum

Aalmen, Frode  
*Drama in teaching Nature of Science - Development and testing of a curriculum about history of physics*  
Supervisor: Berit Bungum
DOCTORAL THESIS

Haugen, Håvard
Spin and Charge Transport in Two-dimensional Electron Gases
Supervisor: Arne Brataas

Mumm, Florian
Interactions of High Aspect Ratio Nanostructures and Biological Systems
Supervisor: Pawel Sikorski

Saxegaard, Magne
Scanning tunneling microscopy based point-contact measurements of nanoscale magnetic systems
Supervisor: Erik Wahlström

Solberg, Marius Aa.
Dark matter candidates and their indirect detection
Supervisor: Michael Kachelriess

Strandberg, Rune
Theoretical studies of the intermediate band solar cell
Supervisor: Turid W. Reenaas

Sæterli, Ragnhild
Electronic structure of thermoelectric and ferroelectric materials: Advanced transmission electronmicroscopy studies
Supervisor: Randi Holmestad

Tørå, Glenn
Pore-scale modelling of two-phase flow: dynamic effects and electrical response
Supervisor: Alex Hansen

Photo: Irene Aspel
PARTICIPATION IN COMMITTEES

EVALUATION COMMITTEES

Andersen J.O:

Borg, A.:
* Opponent at the PhD defence of Krithika Venkataramani, Interdisciplinary Nanoscience Center and Department of Physics and Astronomy (iNANO), Aarhus University, June 2010.
* Opponent at the PhD defence of May Lin Ng, Department of Physics, Astronomy, Molecular and Condensed Matter Physics, Uppsala University, November 2010.
* Evaluation committee for appointing professor in Nanoscience and Outreach Activities, Department of Physics, Denmark Technical University.

Breiby, D.W.:
* Administrator for the PhD defense of Florian Mumm, NTNU

Bungum, B.:
* Member of PhD evaluation committee for Claes Klasander (Norrköping, Sweden)
* Member of PhD evaluation committee for Barbro Gustafsson (Växjö, Sweden)

Davies C. de L.:
* Evaluation committee for application on infrastructure to the regional health authorities Helse Sør-Øst
* Evaluation committee for Dr.Philos thesis submitted by Gunnar Myhr
* Opponent for PhD thesis of Øyvind Sverre Svenden, University of Bergen, February 2010

Espy, P.:
* Opponent for PhD defence of Margit Dyrland, Department of Physics, University of Tromsø, February 2010.
* Member of PhD evaluation committee for Bengt Rydberg, Department of Radio and Space Science, Chalmers University of Technology, February 2010
* Member UNIS advisory committee for Arctic Geophysics, 2010.

Gibson, U.:
* Faculty hiring board, American University of Kuwait

Holmestad, R.:
* Administrator for PhD defense of Chang You, (Electronics and Telecommunication, NTNU, Febr. 2010), Rune Strandberg (Physics, May 2010) and Magne Saxegaard (Physics, October 2010).
* Evaluation committee for assistant professor at Chalmers, May 2010.

Linder, J.:
* Secretary for "Oppfølgingsutvalget for fysikkfagene" spring 2010.

Reenaas, T.W.:
* Evaluation committee PhD thesis of Elisa Antolin, Universidad Politécnica de Madrid, January 2010

INTERNATIONAL COMMITTEES

Borg, A.:
* Member of the “Beredningsgrupp 2” under the Committee of Research Infrastructure (KFI), The Swedish Research Council, Sweden.
* Member of the board of MAX-lab, Lund University, Sweden.
* Member of the board of The Nanometer Consortium, Lund University, Sweden.
* Member of Administrative Council of SEFI (European Society for Engineering Education)

Brataas, A:  
* Member of the International Union of Pure and Applied Physics (IUPAP), Commission on Quantum Electronics.

Bungum, B.:
* Editor of scientific journal NorDiNa (Nordic Studies in Science Education).
* Coordinator of Nordic research network, NorSEd

Espy, P.:
* Member SCOSTEP Climate and Weather of the Sun-Earth System (CAWSES-II) Task Group 2, 2010.
* Member International ALOMAR Science Advisory Committee, 2010.
Fossum, J. O.:  
* Project leader of a Nordforsk funded Nordic Researcher Network in Soft Matter Physics (2010-2013) involving ~100 scientists in ~10 groups in the Nordic countries (Denmark, Finland, Norway, Sweden)  
* 2010 - In International Scientific Advisory Board for Center of Physics, Minho University, Braga, Portugal  
* 2010 - In International Scientific Advisory Board for International Center for Condensed Matter Physics (ICCMP), Universidade de Brasilia (UnB), Brasilia, Brazil

Gibson, U.:  
* Optical Society of America Tellers committee chair  
* Editorial Board, Materials Characterization (Elsevier)  
* Editorial Board, NanoEthics (Springer)  
* International Commission for Optics, Board member

Hansen, A.:  
* Secretary to the Board of European Physical Society's Computational Physics group.  
* Member of the International Union of Pure and Applied Physics (IUPAP), Commission of Computational Physics (C20).  
* Member of the Scientific Advisory Board to the Center of Excellence in Computational systems Research, Helsinki University of Technology  
* Member of the ESF Network “Exploring the Physics of Small Devices” steering committee.  
* Member of the Editorial board of the European Journal of Physics  
* Member of the Editorial Board of the International Journal of Modern Physics C

Holmestad, R.:  
* Member of the board of the Nordic microscopy society, SCANDEM.  
* Leader of the Nordic network within TEM – NorTEMnet

Kachelriess, M.:  
* Member of the steering committee of ”ISAPP: International School on AstroParticle Physics European Doctorate School”  
* Member of the Organizing Committee of the workshop ”Theory and observations of extragalactic magnetic fields”, Paris 2010  
* External evaluator for Vidi-research proposals of NWO (Netherlands Organisation for Scientific Research)

Kjeldstad, B.J.:  
* Member of World Meteorological Organisation, Scientific advisory Group for Ultraviolet Radiation measurements (WMO UVSAG).

Stokke, B.T.:  
* Editorial Advisory Board – Biopolymers (Wiley).  
* Core expert, study program accreditation in Nanoscience and Applied Physics, ACE Denmark  
* Evaluation of Strategic University College Funding, The Norwegian Research Council, Committee member  
* Research proposal reviewer, Wellcome Trust-India Alliance  
* Scientific advisory board, Polymer Networks conferences, 2010 (Germany)  
* International Advisory Board, 10th International Hydrocolloids Conference, 20-24 June 2010, Shanghai Jiatong University, Shanghai, China.

A. Sudbø:  
* Steering Committee Member, European Science Foundation Network on Nanoscience and Engineering in Superconductivity (NES).  
* Member of ESA’ Physical Sciences Working Group, European Space Agency

NATIONAL COMMITTEES

Andersen, J.O.:  
* Member of the board of the group for subatomic and astrophysics in the Norwegian Physical Society.

Borg, A.:  
* Chair of “Programme for Synchrotron Research”, Research Council of Norway.  
* Member of the Board for the Niels Henrik Abel Memorial Fund

Bungum, B.:  
* Member of the board for “Nasjonalt netverk for naturfagutdanning” (National network for science education).  
* Member of committee for proposing in-service teacher education in engineering colleges, organised by the National council for technological education.

Davies, C. de L.:  
* Node leader and Platform leader of the FUGEII supported nation network “Norwegian Molecular Imaging Consortium”.  
* Member of the board of the National Interdisciplinary Research School in Medical Technology
### Participation in Committees

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Espy, P.</td>
<td>* Member UNIS advisory committee for Arctic Geophysics, 2010.</td>
</tr>
<tr>
<td>Fossum, J.O.</td>
<td>* Member of the Board of the Norwegian Physical Society</td>
</tr>
<tr>
<td></td>
<td>* Chair of the Division for Condensed matter Physics with Atomic Physics in The Norwegian Physical Society</td>
</tr>
<tr>
<td>Hansen, A.</td>
<td>* Member of Board of Trustees, National Museum of Applied Arts, Trondheim.</td>
</tr>
<tr>
<td>Holmestad, R.</td>
<td>* Member of the board of ‘Bardalfondet’ (Fond for belønning av fremragende studentarbeid innen økologiske aspekt av materialteknologi ved NTNU)</td>
</tr>
<tr>
<td>Johnsson, A.</td>
<td>* Member of steering group (Norwegian Defence Research Establishment) for project:</td>
</tr>
<tr>
<td></td>
<td>“Electromagnetic fields and human reproduction health” (Univ. of Bergen).</td>
</tr>
<tr>
<td>Kjeldstad, B.J.</td>
<td>* Member of advisory board of Sintef, Material and Chemistry</td>
</tr>
<tr>
<td></td>
<td>* Member of the Board of University of Svalbard</td>
</tr>
<tr>
<td>Lindmo, T.</td>
<td>* Chairman of Norwegian national committee for the evaluation of professor competence in physics.</td>
</tr>
<tr>
<td>Stokke, B.T.</td>
<td>* Chairman of the board (to summer 2009), Board member (from summer 2009), NANO MAT Research Program, The Norwegian Research Council</td>
</tr>
<tr>
<td>Sudbø, A.</td>
<td>* Member, National Working Group for FUNMAT.</td>
</tr>
</tbody>
</table>

### University and Departmental Committees

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
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</thead>
<tbody>
<tr>
<td>Andersen J.O.</td>
<td>* Organizer of Friday Colloquia at the Department of Physics.</td>
</tr>
<tr>
<td>Borg, A.</td>
<td>* Member of FUS (“Forvaltningsutvalget for sivilingeniørutdanningen”) at NTNU.</td>
</tr>
<tr>
<td></td>
<td>* Vice dean on education, Faculty of Natural Sciences and Technology.</td>
</tr>
<tr>
<td></td>
<td>* Member of FUL (“Forvaltningsutvalget for Lærerutdanningen”) at NTNU.</td>
</tr>
<tr>
<td></td>
<td>* Member of Educational Committee of NTNU</td>
</tr>
<tr>
<td></td>
<td>* Member, “Studieprogramråd for Lærerutdanningen i Realfag”.</td>
</tr>
<tr>
<td></td>
<td>* Member of the board at Department of Industrial Economics and Technology Management</td>
</tr>
<tr>
<td>Brataas, A.</td>
<td>* Chairman of the board of “Realfagsbiblioteket”.</td>
</tr>
<tr>
<td></td>
<td>(on sabbatical leave 2010-2011)</td>
</tr>
<tr>
<td>Breiby, D.W.</td>
<td>* Elected member of the Departmental Board.</td>
</tr>
<tr>
<td>Bungum, B.</td>
<td>* Member of the board for “Programråd for Lærerutdanning i Realfag”</td>
</tr>
<tr>
<td>Davies, C. de L.</td>
<td>* Director of NTNU’s Strategic Area of Medical Technology.</td>
</tr>
<tr>
<td></td>
<td>* Member of the program committee in Bioinformatics.</td>
</tr>
<tr>
<td>Gibson, U.</td>
<td>* Member leader group “Gemini Centre Solar Cell Materials&quot;</td>
</tr>
<tr>
<td></td>
<td>* Member of the Nanolab leadership committee</td>
</tr>
<tr>
<td>Hansen, A.</td>
<td>* Member of “Fakultetets sakkynige kommite”</td>
</tr>
<tr>
<td>Holmestad, R.</td>
<td>* Leader of the TEM Gemini Centre</td>
</tr>
<tr>
<td></td>
<td>* Member of Faculty of Natural Science and Technology (NT) board</td>
</tr>
<tr>
<td></td>
<td>* Member of NTs ’Forskningsutvalg’.</td>
</tr>
<tr>
<td></td>
<td>* Member of NTs ’Ansettelsesutvalg’</td>
</tr>
<tr>
<td></td>
<td>* Deputy Department head (Research), Department of Physics</td>
</tr>
<tr>
<td></td>
<td>* Chairman ‘Formidlingsutvalget’, Department of Physics</td>
</tr>
</tbody>
</table>
Kjeldstad, B.:  
* Head of the Department of Physics (until August).  
* Member, board Geminisenter for PV materials  
* Member, board TEM Geminisenter  
* Member of NT leadergroup  

Linder, J.:  
* Member of ‘Formidlingsutvalget’, Department of Physics  

Lindgren, M.:  
* Chairman, Division of Applied Physics and Didactic Physics  

Lindmo, T.:  
* Chairman, Division of Biophysics and Medical Technology.  
  * Member, “Studieprogramråd for fysikk og matematikk”.  
  * Chairman, “Studieprogramråd for International MSc Medical Technology”.  

Mikkelsen, A.:  
* Chairman, Division of Complex Materials  

Reenaas, T.W.:  
* Member leader group “Senter for fornybar energi”  
  * Member leader group “Gemini Centre Solar Cell Materials”  
  * Member, “Studieprogramråd for MSc Condensed Matter Physics”.  
  * Substitute for the Elected member of the Departmental Board.  

Sikorski, P.:  
* Acting chairman of detail planning committee for the bionanotechnology clean room, NTNU Nanolab.  
  * Member, Ledergruppen NTNU Nanolab.  

Stokke, B.T.:  
* Chairman of the board, NTNU Nanolab, NTNU.  

Støvnen, J.A.:  
* Chairman, “Undervisningsutvalget ved institutt for fysikk”.  
  * Member, ”Studieprogramråd for MSc Fysikk og matematikk”  

Sudbø, A.:  
* Head of the Department of Physics  

Wahlstrøm, E.:  
* Acting director/ Director NTNU NanoLab  
* Chairman, Division of Condensed Matter Physics  
* Member, ”Studieprogramråd for nanoteknologi”.  

Overbo, I.:  
* Chairman, “Studieprogramrådet for Realfag”.  

ARRANGEMENT COMMITTEES  

Fossum J.O.:  
* Main organizer of International Workshop on Complex Physical Phenomena in Materials, GoldenTulip Recife Palace Hotel, Boa Viagem, Recife PE, Brazil, December 14-17 2010  
* Main organizer of International Workshop on CO2 and Fluids in Nanoscience, International Center for Condensed matter Physics (ICCMP), Universidade de Brasilia (UnB), Brasilia, Brazil, December 7-10 2010  
* Main organizer of Mini-Workshop on Complex Matter Physics, NTNU in Trondheim, Norway, September 20&21 2010 (Co-organized with Onsager Prof. E. Bouchaud CEA-SAACLAY Paris)  

Hansen, A.:  
*Chairman of CCP2010, IUPAP Conference on Computational Physics, Trondheim, June 23-26.  

van Helvoort, A.T.J.:  
* Member scientific committee 10th International Congress for Applied Mineralogy (ICAM) in Trondheim, Norway on 1-5 August 2011.  

Holmestad, R:  
* Conference co-chair for Japan-China-Norway Cooperative Symposium on Nanostructure of Advanced Materials and Nanotechnology (JCNC52010), Toyama, Japan, 12-13. Sept 2010  

Kildemo, M.:  
* Member of program committee for the 5th International Conference on Spectroscopic Ellipsometry, ICSE Albany, 22-28 May 2010  

Reenaas, T.W.:  
FRIDAY COLLOQUIUM

PROGRAM – SPRING TERM
Convenors: Razi Naqvi and Jens Oluf Andersen


12. February: Einar Halvorsen, Høgskulen i Vestfold: ”MEMS vibration energy harvesting”


30. April: Børge Arntsen, Inst. for petroleumsteknologi og anvendt geofysikk, NTNU: “ECHOES OF THE EARTH: How to make images of the crust of the earth”


Note - Two Colloquiums were cancelled due to volcanic activity in Iceland:
16. April: Jan de Boer, University of Amsterdam: “Holography, quantum gravity and black holes”


PROGRAM – AUTUMN TERM
Convenors: Kåre Olaussen and Jan Myrheim

3. September: Phil Scott, NTNU and University of Leeds: “Why physics is difficult to teach and hard to learn”

9-10. September: No regular colloquium this week due to Kavli Prize Seminars on September 9th. “Kavli Prize Lectures & affiliated symposia in Nanoscience and Neuroscience at NTNU”

17. September: Håkon Dahle, Inst. for teoretisk astrofysikk, UiO: “The biggest lenses in the universe - and what we can learn from them”

20. September: Yves Couder, Matière et Systèmes Complexes, Université Paris Diderot: “A macroscopic type of wave-particle duality: The role of a "path memory" in the motion of bouncing droplets”

1. October: Geir Helgesen, Physics Department, Institute of Energy Technology: “Structure and Properties of Carbon Cones”

15. October: Margrethe Wold, Dark Cosmology Centre, Niels Bohr Institute: “The co-evolution of supermassive black holes and galaxies”

22. October: Arne Espelund, NTNU: "Karbonkontroll ved framstilling av jern”

29. October: Magnus H. Sorby, Physics Department, Institute for Energy Technology: “Neutron scattering at IFE”


19. November: Jan de Boer, University of Amsterdam: “Holography, quantum gravity and black holes”
