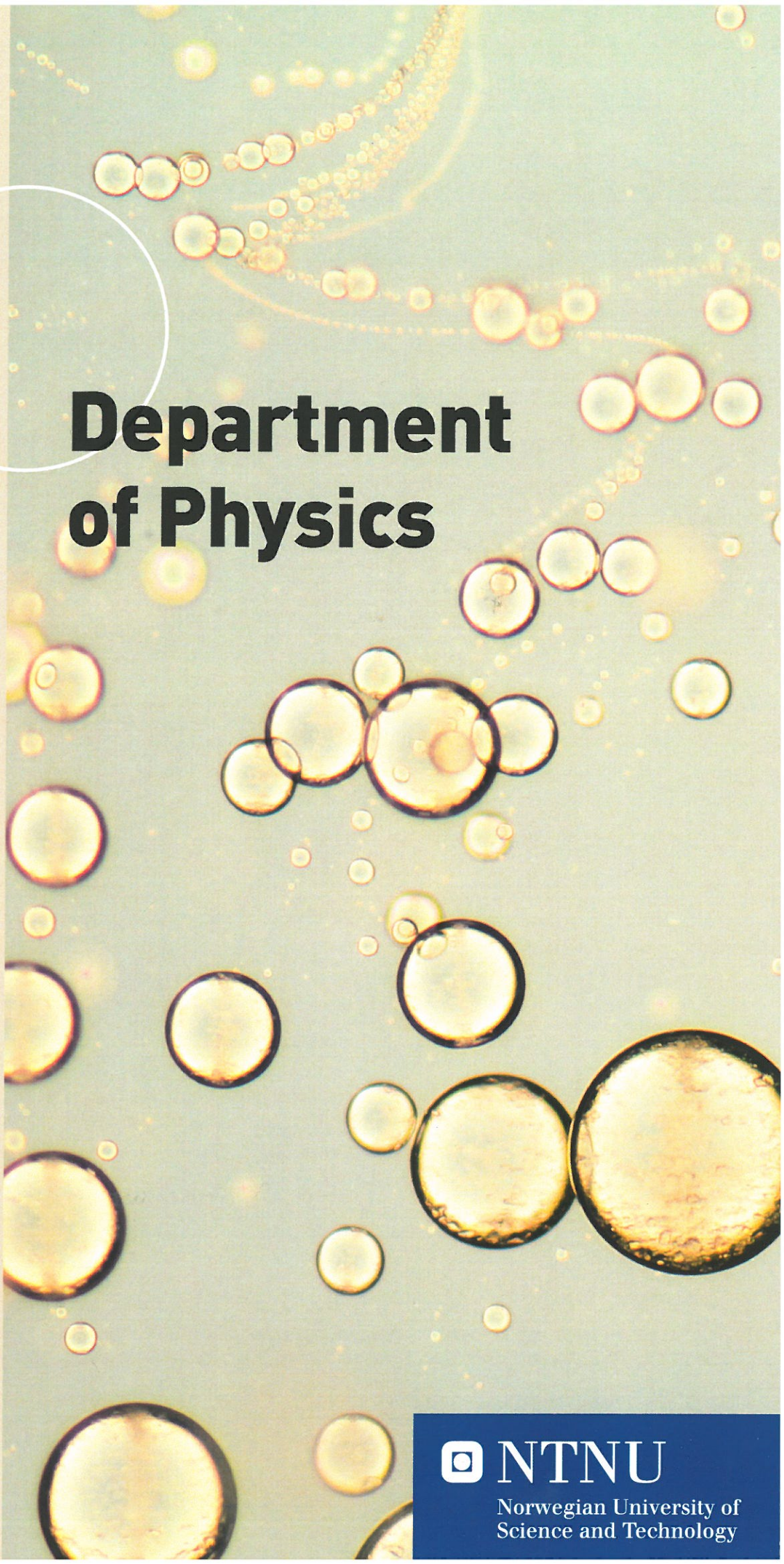
Department of Physics

Annual Report 2012



NTNU
Norwegian University of Science and Technology

DEPARTMENT OF PHYSICS, NTNU

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Head of Technical Staff:	Per Magne Lillebekken

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COVER PAGE:

1 mm radius droplets of silicon oil, in a container of castor oil, with clay particles self-organizing inside the droplets. The container is exposed to an applied electric field.

DEPARTMENT OF PHYSICS, NTNU

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CONTENTS

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Eli Ljøkelsøy Monsøy, Peder Kristian Brenne, Aud Lise Kulseth og Asle Sudbø

The Annual report is also available on the internet address:

STAFF

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ACCOUNTS 2012

	Amount kNOK
GOVERNMENT UNIVERSITY FUNDING (including NTNU strategy projects)	**79 288**

PROJECTS FINANCED BY THE RESEARCH COUNCIL OF NORWAY

Project	Project manager	Amount kNOK
Understanding catalytic effects i Pd alloy model systems	Borg Anne	813
Understanding catalytic effects i Pd alloy model systems	Brataas Arne	162
ColdWear	Breiby Dag Werner	784
Towards nanoscale 3D imaging of working catalyst nanoparticles	Breiby Dag Werner	1 275
Norwegian Molecular Imaging Consortium	Davies Catharina	2 919
Gravity-wave sources and scales in the Polar Regions	Espy Patrick Joseph	785
Complex systems and soft materials	Fossum Jon Otto	337
Sorption and Migration of CO2 in Porous Media	Fossum Jon Otto	2 219
Prosjektetableringsstøtte	Fossum Jon Otto	190
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Stimulated production: Steady and NonSteady State	Hansen Alex	739
Efficient CO2 Absorption in Water-Saturated Porous Media	Hansen Alex	1 591
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Fracture propagation, INDNOR	Hansen Alex	20
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Kimdanningskontroll for Optimaliserte Egenskaper	Holmestad Randi	642
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	Sum	**42 814**

CONTRIBUTION FROM OTHER FINANCIAL SOURCES

Contributors	Project name	Project manager	Amount kNOK
SIU	PhD Programme	Andersen Jens O.	35
EU FP7	Magneto Caloritronics	Brataas Arne	2 796
Sør-Trøndelag Fylkeskommune	Force-in-Action	Bungum Berit	14
Nordforsk	Nordic Science Education Network	Bungum Berit	322
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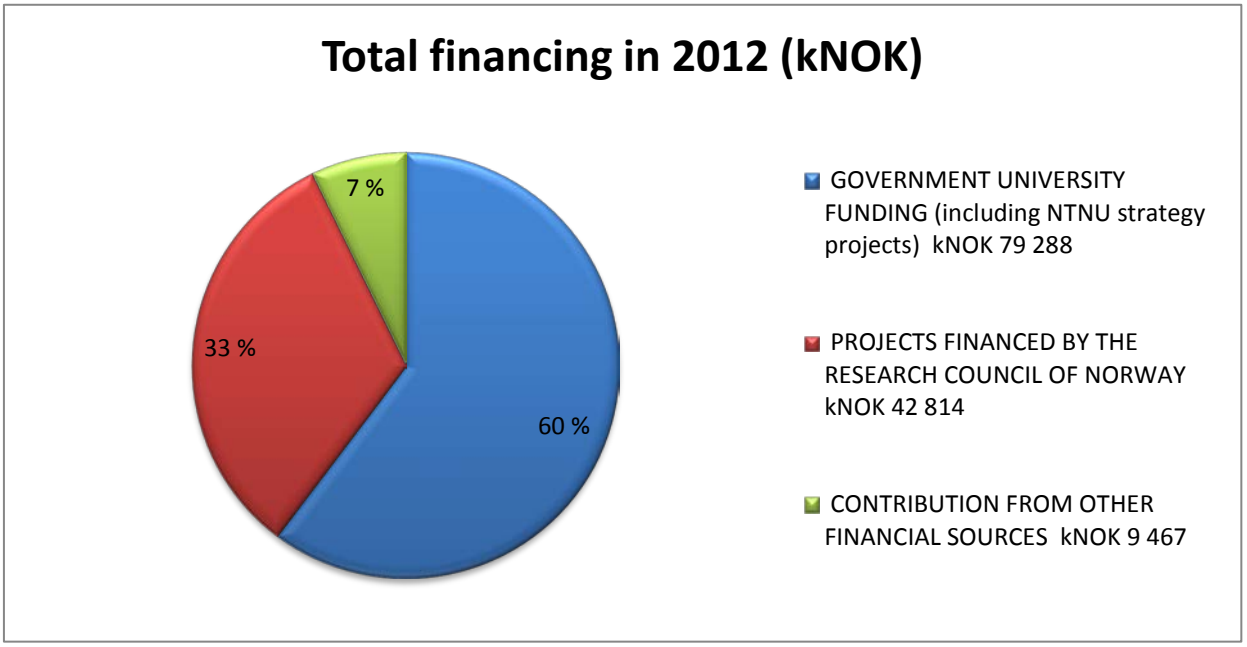
Total external accounts in 2012	**52 281**



AWARDS

Space Physics Project Became Part of Birkeland Centre for Space Science

The Professors Patrick Espy and Robert Hibbins at The Department of Physics, have been included in The Birkeland Centre for Space Science. In 2012 the Centre was appointed as one of thirteen Centres of Excellence.

PhD Amna Noreen awarded Certificate of Merit for Best Talk

PhD Amna Noreen at the Section of Theoretical Physics was awarded the Certificate of Merit for her talk at the 2012 International Conference of Computer Science and Engineering. The award is one of two granted for best PhDs based on originality, significance, correctness, and clarity.

PhDs Jostein Bø Fløystad and Vidar Fauske's Talks Awarded

The two PhDs at The Section of Condensed Matter Physics, Jostein Bø Fløystad and Vidar Fauske, were awarded for their talks. The first (above) for best talk at the annual meeting in The Nordic Microscopy Society, the latter (below) for best talk at the National Research School for Nano Technology for Microsystems.

Physics Students Awarded at Faculty Graduation Ceremony

At the annual Graduation Ceremony, the Faculty for Natural Science and Technology awarded two physics students. The Faculty's award for best MSc in Technology went to Hans Langva Skarsvåg (above) at the programme Master of Science in Technology – Applied Physics and Mathematics.

The award for best PhD at NTNU and the Exxon Mobile Research Prize 2012 went to Kjetil M.D. Hals (below) for his dissertation «Current-induced Dynamics in Ferromagnets and Antiferromagnets». At the ceremony it was emphasized that Hals already has published six articles as main author.

Professor Arne Brataas at the Section of Theoretical Physics has supervised both MSc Skarvåg and PhD Hals.

Biophysicists got Research Prize in Medical Technology

At the NTNU's annual party for all employees, an interdisciplinary research group – including physicists at Section of Biophysics and Medical Technology, were honoured a research prize in medical technology. The research group has developed an interferometric technique to determine the thickness of hydrogels.

HIGHLIGHTS FROM THE ACTIVITY

Jacob Linder selected by APS as an Outstanding Referee

American Physical Society (APS Journals) annually provides a highly selective Outstanding Referee award to a limited number of referees who have been exceptionally helpful in assessing manuscripts for publication in the APS journals. The editors of APS journals select the honorees based on the quality, number, and timeliness of their reports, without regard for membership in the APS, country of origin, or field of research.

In 2012, Jacob Linder was selected by APS as an Outstanding Referee among roughly 60.000 active referees.

RESEARCH

SECTION OF APPLIED PHYSICS AND DIDACTIC PHYSICS

Head of Section
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Professor Robert Hibbins
Professor Morten Kildemo
Professor Mikael Lindgren
Professor Ingve Simonsen
Professor Irina Sorokina
Assoc. professor Berit Bungum
Assoc. professor Jonas Persson
Assoc. professor Knut Arne Strand
Assoc. professor Turid Worren Reenaas

Research staff
Postdoc. Vladislav Dvoyrin
Postdoc. Maria Jerôme
Postdoc. Nikolai Tolstik
Postdoc. Xiaodong Yang

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; atmospheric, energy 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)*.

Atmospheric, energy and environmental physics includes studies of climate processes, including atmospheric dynamics, composition and UV-irradiance, as well as the influence of solar radiation and energetic particles on the atmosphere (*Espy, Hibbins and Kjeldstad*,). It also includes research in solar energy such as intermediate band solar cells, as well as new absorber materials and concepts (Reenaas and Gibson).

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 2012 we have chosen to give a more thorough account of two specific research projects carried out in Energy and Environmental research and Applied Optics and Laser Physics.

Survey of research activities

Intermediate band solar cells
(T. W. Reenaas, U. Gibson, S. F. Thomassen, M. Gholami, M. Nematollahi, X. Yang and S. Polyakov)

The intermediate band (IB) solar cell is a relatively new solar cell concept that has efficiency limits 50% higher than for conventional solar cells. The Solar cell physics group at the Department is involved in both theoretical studies of such cells and in fabrication of new materials for the realization of these devices.

For the realization of IB solar cells the group is attempting two different approaches to form the intermediate band in the bandgap: 1) quantum confinement in quantum dots (QDs) and 2) ultrahigh doping with elements forming deep levels. The QD material system studied has been InAs QDs in a GaAs or $Al_{0.35}Ga_{0.65}As$ matrix. The QDs are fabricated using molecular beam epitaxy (MBE) in collaboration with Prof. Bjørn-Ove Fimland at the Department of electronics and telecommunication, NTNU. The focus has been to optimize the growth parameters to achieve as high QD density as possible, to increase the absorption coefficient below the matrix bandgap. Very QD densities, above 10^{17} cm^{-3}, have been achieved which is in the range of what is needed. An increased understanding of the nucleation and growth of InAs/AlGaAs QDs has been achieved, in part by studying the topography of uncapped QD layers, see Figure 1.

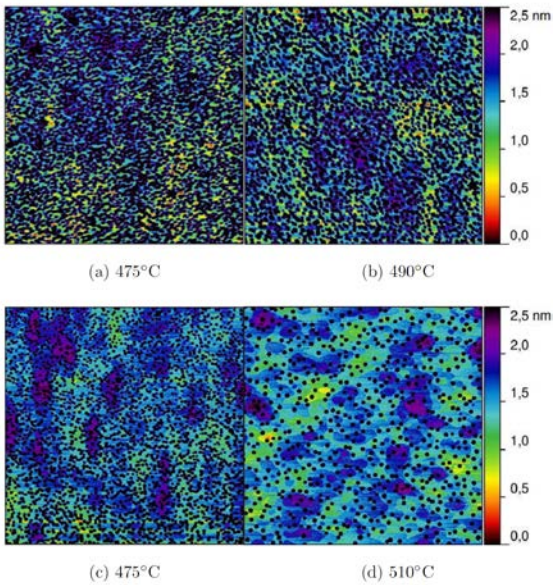

Figure 1. 2×2 μm^2 AFM images showing the surface topography for uncapped QDs grown on GaAs with continuous InAs deposition at 475 ˚C (a) and 490 ˚C (b), and pulsed InAs deposition at 475 ˚C (c), and 510 ˚C (d).

For the formation of an IB by ultrahigh doping we have selected Cr-doped ZnS as the material system. Thin films of un-doped and doped ZnS have been deposited on p-doped Si using MBE and pulsed laser deposition (PLD). ZnS/Si and Cr:ZnS/Si hetero-structure devices have been fabricated, and their performances have been tested for 1 sun AM1.5 illumination. For the device with Cr-doped ZnS the current generation is enhanced compared to the device with un-doped ZnS.

The FP7 project LUPAS -
(M. Lindgren)

In Alzheimer's disease (AD) and similar neuro-degenerative disorders, the accumulation of protein aggregates, called amyloids, is central to their pathogenesis. The EU FP7-project LUPAS, with 10 partners from Norway, Sweden, Germany, France, Switzerland and Israel, developed novel agents and methods for diagnostic imaging, based on reporter molecules based on luminescent conjugated polythiophenes, LCPs. In the project the Applied Optics group participated as leader of the important 'imaging technologies' work-package. The project terminated 31 of Dec 2012.

The LCP molecules can target pathogenic protein aggregates with high selectivity and specificity, and a library of more than 15 different LCP-types were designed tested and tried in experiments (in vivo as well as stained sections) of AD mouse models.
LUPAS also generated different amyloid molecular targets *in vitro* and screened the LCP library towards these targets. Both Multiphoton imaging as well as hyperspectral imaging were used to assess the diagnostic capability of these molecular probes. The former is an excellent technique for studying protein aggregation diseases in real time in living transgenic mouse models. The consortium showed that the unique optical properties of LCPs make these dyes highly efficient for multiphoton imaging *in vivo*. Several LCPs cross the blood–brain barrier and specifically label amyloid plaques in the parenchyma, deposits in the vasculature, as well as intraneuronal Tau in transgenic mouse models with AD pathology. The diagnostic efficacy in humans has been demonstrated in post-mortem tissue sections from patients with AD and prion diseases. The LUPAS consortium also aimed to develop novel multimodal LCPs that can be used for both optical imaging and MRI. Contrast agents based on paramagnetic nanoparticles and nanocomplexes (MNPs) hold great promise for MRI. Within LUPAS, a variety of nanoparticles were synthesized showing enhanced T1 and T2 relaxation dispersion rendering potent contrast agents for MRI. The first prototype of a LCP-MNP conjugate can specifically target amyloid *in vitro*, in tissue samples, and promising results have also been obtained *in vivo* in transgenic mice. In terms of therapeutics, the LCP based molecules conceptualized a mechanism based on hyperstabilization of prion aggregates as an avenue for therapeutic intervention of prion disease. This track is especially intriguing for rapid disease progression but is also of interest for slow onset dementia such as Alzheimer´s disease.

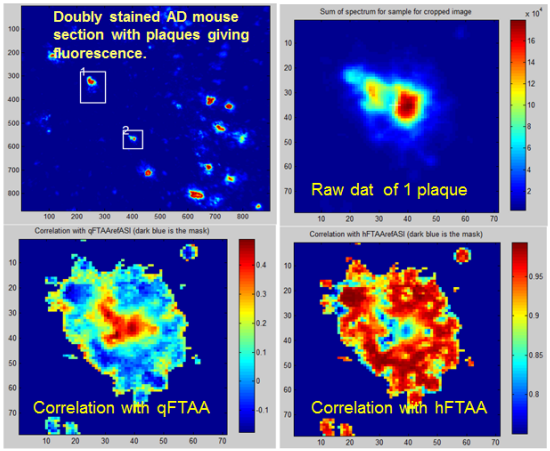

Figure 2 – Top panels: Raw image of microscopy uptake of AD mouse plaque sections double stained. Left panel shows raw microscopy imaga with hyperspectral fluorescence content. Lower panels: Examples of correlation analysis developed at NTNU of selected plaque. One can see that the stain qFTAA is more prominent in centre of plaques compared to hFTAA.

The contribution from the Applied optics group was mainly in the recording of a data-base spectral information of various LCP-amyloid combinations, and advanced spectroscopic and image analysis of data. We successfully developed and introduced a new mathematical algorithm based on cross-

correlation that allows detection of weak fluorescence signals in hyperspectral images, and showed how these can be used to model structural changes of amyloid deposits in mouse models from approx. 6 months up to 2 years of age. Some examples of the use of the algorithm are shown in Figures 1 and 2. Further details are in the progress of being published in scientific journals.

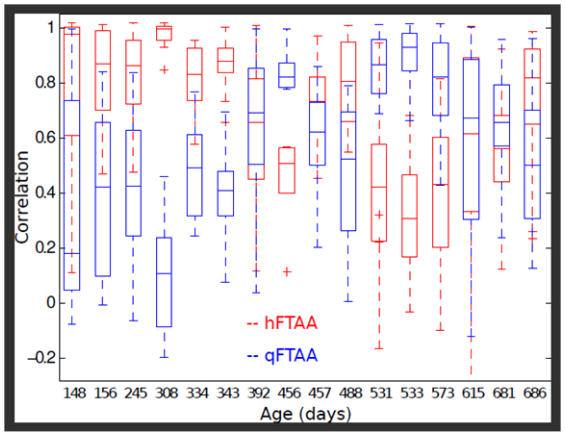

Figure 3 - Changes of central plaque structure in terms of correlation of the different stains qFTAA and hFTAA for APP/PS1 AD mice at different ages.

SECTION OF BIOPHYSICS AND MEDICAL TECHNOLOGY

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Assoc. professor Marit Sletmoen
Adjunct professor Tor Wøhni

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Postdoc. Sylvie Lelu
Postdoc. Heng Li
Postdoc. Katarzyna Psonka-Antonczyk
Postdoc. Nina Reitan

Overview

The research is presented under the following headings*: Medical physics and technology*, *Biopolymers and bionanotechnology*, and *Photobiophysics*. In the former section, an example of research, on dosimetry for breast cancer irradiation, is described in more detail.

Survey of research activities

Medical physics and technology

Monte Carlo study of flattening-filter-free beams in tangential breast cancer irradiation
(S. Saur Almberg, J. Frengen, T. Lindmo)
Many radiotherapy departments have a long tradition of using 6 MV photons for tangential breast irradiation, and this beam quality is considered favourable concerning the balance between dose coverage in the clinical target volume (CTV) and skin sparing effect. With the introduction of intensity-modulated radiotherapy (IMRT), the flattening filter in conventional linear accelerators is principally no longer needed, and so-called flattening-filter-free (FFF) beams have gained interest over the past few years. As the flattening filter absorbs low-energy photons, an FFF beam will have a "softer" spectrum than an FF beam. This softer spectrum in turn results in a more shallow build-up region and a steeper depth-dose curve. However, depth-dose characteristics similar to the original beam can be obtained by increasing the energy of the electrons hitting the bremsstrahlung target, from 6.45 MeV for the FF beam to 8.0 MeV for an equivalent FFF beam.

The purpose of the present work was to evaluate and compare the dosimetry related to conventional and flattening-filter-free (FFF) beams in tangential breast cancer irradiation. Three tangential breast irradiation plans were simulated by utilizing one "6 MV" conventional beam model and two flattening-filter-free (FFF) models, one at the energy of the conventional beam (6.45 MV), and one at the increased energy of 8.0 MV. For similar dose distributions to the clinical target volume, the dose distributions in the skin (0-5 mm depth), contralateral breast (CLB), ipsilateral lung (ILL), and the region outside the main fields ("non-CTV") were analysed and compared.

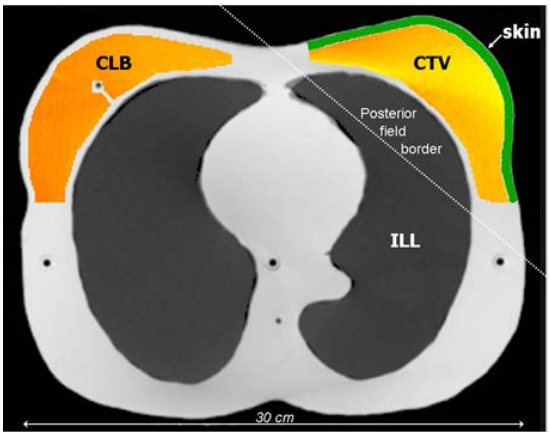

Figure 1. Axial CT slice of the phantom used (isocentre plane). Regions of interest are the clinical target volume (CTV), skin, contralateral breast (CLB), and ipsilateral lung (ILL). The phantom region which was more than 1 cm below the posterior field border defined a region denoted "non-CTV".

A phantom made of RW3 (PTW-Freiburg, Germany) and cork, shaped like a female thorax, was used. A transaxial view of this phantom is given in Figure 1, with regions of interest indicated. The CTV and CLB were delineated with 5 mm margin to the phantom surface and lung, while the skin was defined as the region between the CTV and the surface of the phantom, i.e. a 5 mm layer of tissue. In addition, dose data were extracted from the ILL and the "non-CTV" region. Dose distributions in the central axial plane are reported.
The treatment plans utilized tangential fields with aligned posterior field borders. Additionally, one (FF) or two (FFF) field segments were used in each field direction to achieve comparable CTV dose

distributions for the three treatment plans. Although a detailed 3-dimensional dose analysis of the CTV was not in focus in the present study, comparable dose distributions for the plans investigated were needed in order to do a fair comparison of out-of-field dose distributions.

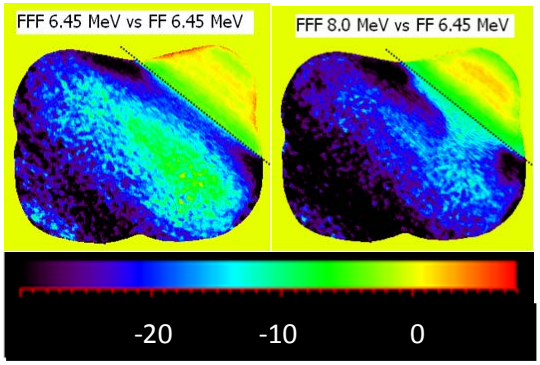

Figure 2. Dose differences in axial isocentre plane for FFF treatment plans relative to the FF treatment plan. Left: FFF 6.45 MeV versus FF 6.45 MeV. Right: FFF 8.0 MeV versus FF 6.45 MeV. The posterior field border is indicated (------). Bottom: Colour code scale (in %) for differences shown in images above.

Dose distributions from the FFF plans were compared with the FF plan, and dose differences are shown in Figure 2. As each plan is normalized to mean CTV dose, the dose levels within the CTV are of comparable value. Although the average skin doses were changed by only a small amount by the use of FFF beams (see Table 1), a dose increase exceeding 5 % for the FFF 6.45 MeV plan could be observed for the most superficial parts of the skin (Figure 2). Thus, dose to the outermost layer of the skin is likely to be increased by the use of FFF beams with non-adjusted initial electron energy. Outside the tangential fields, dose reduction is achieved by both FFF plans. Up to 30 % dose reduction is observed for regions at a few cm distance from the posterior field border. Average doses for the CLB, ILL, and non-CTV regions are shown in Table 1.

Table 1.
Average doses to normal tissues for the FF 6.45 treatment plan, for a total CTV dose of 50 Gy. Dose differences (in %) relative to the FF 6.45 MeV treatment plan are given for the two FFF treatment plans.

Average dose (Gy) or dose difference (%)				
Treatment plan	Skin	CLB	ILL	Non-CTV
FF 6.45 MeV	44.7	0.500	10.52	0.547
FFF 6.45 MeV	1.1%	-24 %	-5.6 %	-19%
FFF 8.0 MeV	-2.2 %	-27 %	-6.2 %	-23 %

As already evident from Figure 2, the FFF treatment plans systematically reduced the doses to these regions compared to the FF treatment plan. The FFF 8.0 MeV plan resulted in a more substantial dose reduction than the FFF 6.45 MeV plan. Of all the regions analysed in the present study, the relative dose reduction achieved by the FFF plans was most pronounced for the CLB.

The present study has demonstrated that FFF beams are likely to represent a general improvement considering reduction of out-of-field doses in tangential breast cancer irradiation, perhaps the most significant effect being reduced CLB dose, and thereby a reduced risk of radiation-induced CLB cancer induction.

Delivery of nanoparticles in tumour tissue and cells
(C. de Lange Davies, S. Lelu, Y. Hansen, M. Afadzi, S. Eggen, S. Hak, Y. Mørch)
Nanomedicine such as liposomes, nanoemulsions, 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 2012 we have focused on two nanoparticles:

Characterization of nanoemulsions and their behaviour in cells and in tumours growing in mice.
Multifunctional nanoparticles (NP) combining contrast agents for imaging and therapeutic agents have opened new possibilities in cancer therapy. The effects of NP surface properties such as hydrophilic polyethylene glycol (PEG) surface coating on the stability of the NP was studied in cell culture and in tumours growing in mice. The NP was found to be stable both in vitro and in vivo. Toxicity studies demonstrated low toxic effects.

Ultrasound mediated drug delivery.
Novel polymeric NPs of poly(butylcyanoacrylate) were developed and characterized. These NPs have the ability to stabilize gas bubbles thereby forming particles to be used for ultrasound imaging and delivery of therapeutic agents. Acoustic and mechanic properties of the gas bubbles were measured. The kinetics of the cellular uptake of the NP and encapsulated model drug (nile red) were studied. In prostate tumours growing in athymic mice, focused ultrasound was found to enhance extravasation and improve the penetration of the NP through the extracellular matrix, although the effect on extravasation was most prominent. The figure below shows that the hydrophobic dye nile

red is taken up in fat cells and NPs were also seen (green). The blood vessels are visualized in red.

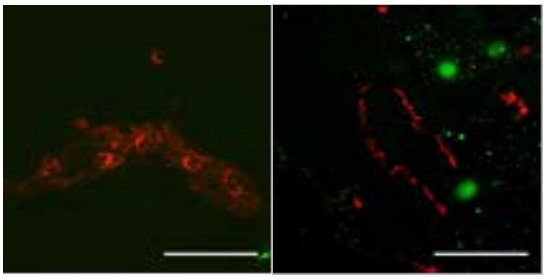

Figure 3. Tumor section from mice not exposed to ultrasound (left) and exposed to 1MHz ultrasound (right). Red: blood vessels, Green: Nile red in fat tissue or in NP.

Clinical applications of multiphoton microscopy

(M. Lilledahl, R. Kumar, E. Romijn)

Multiphoton microscopy is an ideal tool for studying many biological molecules. Many important such molecules like collagen, elastin and several 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.

Stromal changes in breast cancer

(A. Braband, I. Kariuki, A. Bofin, M. Lilledahl)

The cellular component has naturally been the target for most cancer research. In tumor diagnosis, the number, size and shape of the cells are often used for diagnosis. Recently it has been shown that the stromal component plays a major role in the development of the disease. Primarily as a diagnostic marker, as cancers with different degrees of malignancy likely will change their surrounding stroma differently. By using second harmonic generation to image collagen fibers in different areas of the tumor we have shown that the structure of the stromal component can easily be used to differentiate cancer tissue from normal tissue. Currently we are expanding our study to include a larger population to determine if stromal structure can also be used to assess different types of cancers or their outcome.

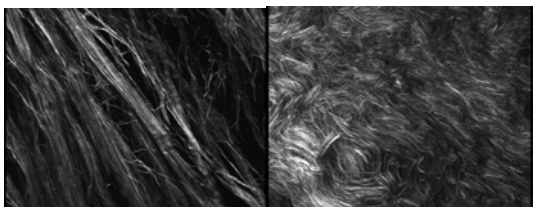

Figure 4. Intratumoral collagen fibers (left) and extratumoral collagen fibers (right).

3D quantitative imaging of collagen structure

(Elisabeth Romijn, Magnus Lilledahl)

In biomechanical models of tissue, the collagen component is an integral part as it imparts the primary stiffness to the tissue. To have accurate models, accurate input parameters regarding collagen structure are needed. Second harmonic generation is an ideal tool for characterizing this structure as it gives a 3D image of the collagen structure without endogenous staining. However, due to an anisotropic point spread function, quantitative analysis is difficult. We have developed an algorithm based on Fourier analysis which quantifies the structure of these fibers and removes the effect of the point spread function. Using this, we can extract quantitative 3D information which is utilized in biomechanical models of for example cartilage.

Tissue engineered cartilage

(M. Olderøy, M. Lilledahl, J.E. Brinchman)

During osteoarthritis, the cartilage covering articular joints is degraded, leading to painful and debilitating conditions. Several surgical repair techniques have been developed but as of yet there are no accepted long term solutions to the problem.

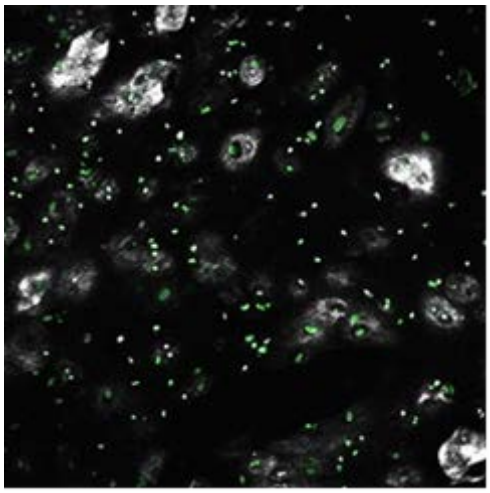

Figure 5. Stem cells (stained with DAPI-green) secrete collagen fibers which align in fibrils, imaged by second harmonic generation (white).

An attractive technique is using stem cells which are seeded in an alginate gel where they differentiate into chondrocytes and start to produce the matrix components which make up cartilage. However, to produce fully functional tissue, the resulting structure is very important. We have been using second harmonic generation to characterize the structure of the matrix and correlate this with different culturing conditions. This will let us optimize the conditions to achieve the optimum tissue structure.

Biopolymers and bionanotechnology

Biopolymer mesoscale structural organization and interactions

(B. T. Stokke, K. Psonka-Antonczyk, D. Barriet, K. Gawel, A. Padol, M. Gao, T. Sherstova, J.M. Ribe, A.G. Håti)

http://home.phys.ntnu.no/brukdef/prosjekter/biopolymerphysics/

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. See the website for further information.

In 2012 we reported thermodynamic data characterizing the polyelectrolyte complex formation between two oppositely charged polysaccharides, xanthan and glucosamine oligo and polymers. The thermodynamic parameters associated with mixing oppositely charged polyelectrolytes in aqueous solutions, leading to spontaneous formation of polyelectrolyte complexes, is thought to possess a major contribution from the change in entropy associated with the release of the counterions. The data obtained for the interaction between xanthan and tri-glucosamine shows that the entropic/enthalpic ratio is largest for the shortest chain length of xanthan. Using a chitosan polymer instead of tri-glucosamine gave rise to two different stages in the interaction process. A model where the first stage of the ITC curve represents an initial polyelectrolyte complexation stage followed by aggregation was presented. Ultrastructure images obtained by AFM were consistent with the two-stage interpretation of the thermodynamic data.

Also in 2012, we reported on direct determination of interaction strength between human Toll like receptor 9 and immunostimulatory (bacterial) CpG-DNA using force spectroscopy. Toll like receptors are involved in the primary recognition and signal transduction cascade in the immunological signaling pathway The molecular recognition forces detected were in the range of 50 to 130 ± 20 pN at the force loading rates employed. The reduction of the molecular interaction probability in the presence of free CpG-DNA demonstrates the specificity of the interaction. Data were consistent with a model for a single barrier in the dissociation pathway. Detailed analysis of the separation at unbinding events supported identification of different regions on the CpG-DNA mediating the molecular interaction. The data thus supported identification of a model for the molecular interaction of this innate immune receptor binding to CpG-DNA.

In 2012 we reported on change of an ionic hydrogel to a polyampholyte hydrogen by the use of impregnation process. Ionic hydrogels swell in aqueous solutions with low salt concentration while contracts on increasing salt concentration. We monitored the deposition of polycations on weakly charged anionic hydrogels and the resulting swelling properties in situ by an interferometric technique with 2 nanometer resolution. Impregnating the anionic hydrogels with low molecular weight polyallylamine resulted in composite materials where the polycation was distributed throughout the polyanionic hydrogel. This composite material displayed swelling response like a polyampholyte when exposed to various salt concentrations in the aqueous solution. The results obtained show that tuning of molecular parameters can be used to control transport properties of polycations into polyanionic hydrogels, and one can prepare composite soft hydrogels with polyampholyte properties.

Single molecule techniques in bionanotechnology

(M. Sletmoen, K.E. Haugstad, N. B. Arnfinnsdottir, J. Nilsen-Nygaard)

Application of single molecule tools based on atomic force (AFM) or optical tweezers (OT) for determination of molecular interactions are central in our activity. In 2012 we reported on quantitative determination of rupture forces and bond lifetimes of self associations occurring between various types of mucins. Mucins are linear O-glycosylated glycoproteins involved in inflammation, cell adhesion, and tumorigenesis and we investigated whether mucins expressing T and Tn cancer antigen oligosaccharides displayed altered self association compared to other mucins. Cancer associated mucins often possess increased expression of the T and Tn antigens being diagnostic markers for several cancers, including colon cancer, and biophysical characterization of these structures is applied to advance molecular understanding of their mechanisms. AFM was applied to obtain single molecule interaction data under near physiological conditions between porcine submaxillary mucin (PSM) as well as between PSM analogs possessing various

carbohydrates including the T- and Tn-antigen. Distributions of unbinding forces and corresponding force loading rates were determined for force loading rates from 0.18 nN/s to 39 nN/s. All mucin samples investigated showed self-interaction, but the tendency was greatest for PSM displaying only the Tn-antigen (TnPSM) or a mixture of Tn-, T-antigen, and another trisaccharide. The data are consistent with the truncated Tn and T glycans enhancing self-interaction of the mucins. These carbohydrate cancer antigens may thus play an active role in the disease by constitutively activating mucin and mucin-type receptors by self-association on cells.

A primary cause of mortality in cystic fibrosis lung disease is hyperviscous mucus leading to a failure of mucociliary clearance, mucus stasis, and bacterial colonization. Most patients eventually succumb to infections with Pseudomonas aeruginosa, which secretes a highly viscous polysaccharide, alginate, exacerbating the problem of hyperviscous mucus through its innate viscosity and its interaction with the mucin polymers that comprise mucus. In 2012 we reported on destabilisation of mucin-alginate interactions by oligoguluronates as determined by forced unbinding of these macromolecular components. The forces needed to rupture bonds formed between purified pig gastric mucin (PGM) and high molecular weight alginate, covalently linked to mica and the AFM tip, respectively, were determined. The experiments were conducted without as well as in the presence of oligoguluronate in a broad concentration range. PGM-alginate forced unbinding profiles revealed unbinding events with magnitudes up to 4 nN occurring at separation distances up to 3 µm. The observed unbinding profiles were consistent with a multivalent nature of the macromolecular interactions. The oligoguluronate concentration-dependent suppression of mucin-alginate interactions could be accounted for by applying a one-site competitive model. These studies outline a possible strategy for screening of potential mucolytic agents.

Bionanotechnology
(P. Sikorski, K. M. Beckwith, J. Torstensen. M. Sandvold, Å. Flobak)
http://www.ntnu.edu/physics/bionano
The group is working in the field of biomaterials and on application of nanotechnology and nanstructured surfaces for biophysics and cell biology research. New large NFR/NTNU financed (Fellesløftet) research project focusing on biomaterial research was started in 2012. The main focus of this project is to further develop the concept of mineralised hydrogels, this time in addition focusing on making hierarchical composite biomaterials, with properties such as composition, mineral phase organization, biocompatibility and mechanical properties controlled over a large range of length scales.

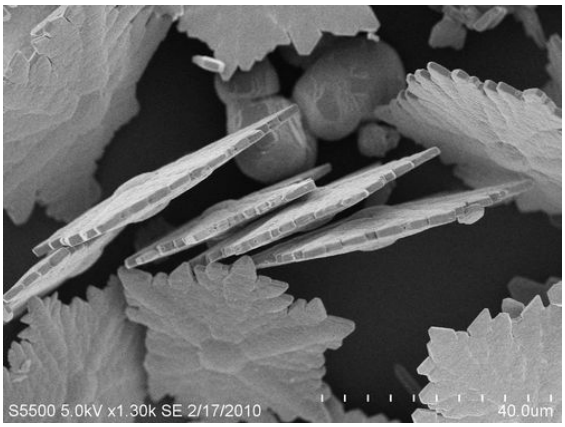

Figure 6. Calcium carbonate crystals visualised with NanoLab's Hitachi S5500 scanning electron microscope. Part of this picture was chosen as new logo for NFR's new large funding program for nanotechnology research (NANO2021). Photo: Magnus Olderøy, Department of Physics, NTNU.

In our research we extensively use NTNU Nanolab, both for characterisation of biomaterials, as well as for development of new nanotechnology-based devices. What sets our approach apart from other studies in the field is a focus on robust, inexpensive and high throughput fabrication methods, as cell biology research often requires large area, single use devices. In addition to device fabrication, we focus on the biophysics of the interface between cells and surface-bound high-aspect ratio nanostructures. Detailed description of this interface is crucial for successful realisation of a nanowire-based platform for delivery of molecular cargo across cell membrane. The concept behind nanowire-mediated delivery relies on the cargo to be delivered being pre-adsorbed onto a surface decorated with vertically aligned nanowires. Cells are cultured on that surface, and it is proposed that as the nanowires penetrate into the cells, the attached cargo is delivered directly into the cells' interior. Our recent experimental observations have highlighted a number of obstacles related to fundamental properties of the cell membrane. In addition we have shown the importance of properly designed control experiments, as the effect of nanowires is not always easy to quantify.

Photo-biophysics.

Photosynthetic systems and pigments
(H. Li, T. B. Melø, K. R. Naqvi)
In higher plants an important role is played by LHCIIb, the major light-harvesting complex of photosystem II (PSII). It is the most abundant

protein in the thylakoid membrane (the site of light-dependent reactions in the chloroplast) and contains about half of its Chl content, and it is involved not only in light-harvesting but also in photoprotection (through an efficient quenching of Chl triplets). LHCIIb consists of three similar subunits (LHCIIb monomers) in a trimeric structure. The identification, position and orientation of all pigments are known; each monomer binds, in addition to six molecules of Chlb and eight of Chla, four carotenoid (Car) molecules, two are lutein (Lut) molecules and one each of neoxanthin (Neo) and violaxanthin (Vio). Monomeric LHCIIb is organized as three transmembrane helices (A, B, C), and two amphipathic shorter helices at the luminal side, named E and D.

In one series of experiments, we have used nanosecond pump-probe spectroscopy to study the formation of Chl triplets and their quenching in LHCIIb, wild type (WT) and four mutants (Y112F, V119F, H120L and S123G) in which a single amino acid (denoted by the last letter) has replaced the amino acid indicated by the first four characters. In another series, we have studied reconstituted LHCIIb wild type (WT) and mutants (five in all) obtained by replacing serine (S123) in the lumenal loop region with glycine (G), proline (P), glutamine (Q), threonine (T), and tyrosine (Y), respectively; S123 is at the edge of the lumenal loop and helix C (the last amino acid in the luminal loop and the first in the helix C). Analysis of the results obtained in these investigations is underway now, and the conclusions will be published in future publications.

The temporal profile of the phosphorescence of singlet oxygen endogenously photosensitized by photosystem II (PSII) reaction centre (RC) in an aqueous buffer is a tall order, but a barely detectable emission signal was recorded and subjected to a kinetic analysis. Extrapolations based on this analysis indicate that attempts to analyse the temporal profile of singlet oxygen in chloroplasts are unlikely to be rewarded with success without a significant advance in the sensitivity of the detection equipment.

A double-beam version of the standard nanosecond laser photolysis method for single-wavelength kinetic studies was developed in order to avoid uncertainties introduced by shot to shot variation in the excitation and monitoring sources.

Conformal relaxation of flexible polymers

(K.R. Naqvi)

Photoexcitation of flexible conjugated polymers is invariably followed by a fast conformational/ torsional relaxation towards a configuration favouring coplanarity of the conjugated segments. In general, the experimental relaxation rate constant k depends on the solvent viscosity (η) and temperature (T), and is not proportional to T/η. A theory capable of explaining the observed dependence of k on T and over a wide range of these variables was not available.

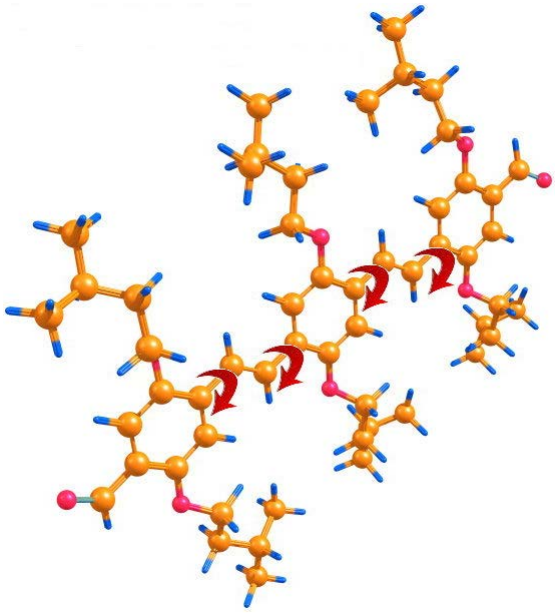

Figure 7. Conformational relaxation of p-phenylenevinylene trimers in non-polar solvents.

This gap was filled in a joint effort by KRN and some scientists from Lisbon towards developing a stochastic model that includes the participation of the oligomer side chain in storing and dissipating the stresses induced by photoexcitation. The model is able to account for the softening of solute-solvent interactions and its predictions are found to be in excellent agreement with the observed relaxation rate constants of a series of substituted p-phenylenevinylene trimers.

SECTION OF COMPLEX MATERIALS

Head of Sectsion
Professor Arne Mikkelsen

Staff
Professor Jon Otto Fossum
Professor Steinar Raaen
Professor Bo-Sture Skagerstam
Assoc. professor Peter Berg
Assoc. professor Bjørnar Sandnes
Adjunct professor Kenneth Dahl Knudsen

Research staff
Postdoc. Zbigniew Rozynek

Overview

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

The research comprises the use of experimental, computational 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; measurements of dynamic viscoelastic properties of soft materials (rheology); microcalorimetry; thermo-gravimetry; dynamic electro-optic properties of soft materials; circular dichroism.

Using *computational methods* we study various complex phenomena including reactive, electro-kinetic flows in rigid and soft porous media.

The *theoretical studies* are mainly on condensed matter physics and statistical physics.

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 Campinas Sao Paulo, Brazil, PAL in Pohang, South Korea, Maxlab Lund University in Sweden. 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, ESPCI-ParisTech, University Rennes 1 in France, University of Amsterdam, University of Havana Cuba, Universidade de Brasilia and other institutions in Brazil.

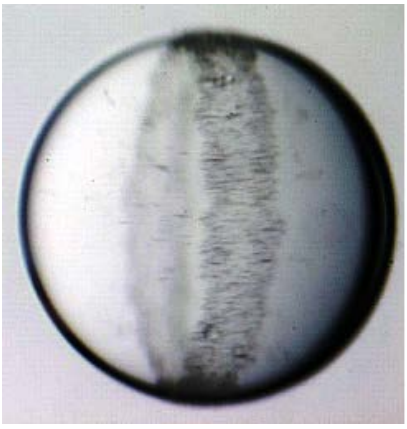

Figure 1. Electric field induced self-organization of clay particles forming a belt on the surface of a micro oildroplet. (A. Mikkelsen, K. Kjerstad, Jon O. Fossum)

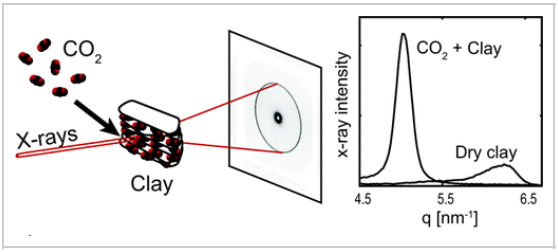

Figure 2. We have shown experimentally that gaseous CO_2 intercalates into the interlayer space of a smectite clay at conditions not too far from ambient. (Hemmen et.al. Langmuir *28* 1678 (2012**))**

Platinum and gold nanostructures on graphite

(Steinar Raaen)

The research activity is focused on studying properties of surfaces that have been modified by doping or nanostructured adsorption layers. The experimental techniques include photoelectron spectroscopy (XPS and UPS), low energy electron diffraction (LEED), temperature programmed desorption (TPD), as well as several in-situ sample preparation techniques. In addition, SEM images are obtained in collaboration with other groups at NTNU.

Figure 3. SEM image of Au/C-nanostructures. The width of the image is about 4 µm.

The adsorption properties of supported metal nanostructures differ from those of the solid surface. The catalytic activity of small gold particles represents an interesting example, since low-index gold surfaces are known to be noble and inactive towards most molecules. The fundamental question is therefore which size-related properties make the gold nanoparticles catalytically active. Nano-particles of gold can, for instance, catalyze CO oxidation at room temperature and below, which is much lower than the temperatures needed for traditional supported metal catalysts. In addition to possessing the catalytic properties of the single crystalline substrate from the same material, a metal nanoparticle array contains new degrees of freedom which influence the reaction output. These are particle size and shape, and the interface between the particles and the support, which typically is a non-metallic surface on which the particles are dispersed.

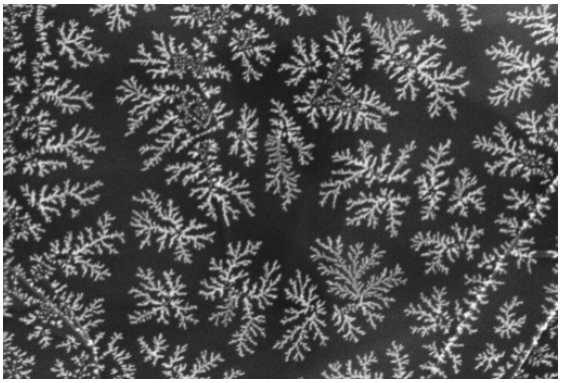

Figure 4. SEM image of Pt/C nanostructures. The width of the image is about 1 µm. The formed patterns resemble those which are formed by diffusion limited aggregation (DLA).

Growth of the structures is performed by evaporation of the metal on the substrate at well-defined temperature. The deposition rate was varied to obtain different structures. Gold on graphite nanostructures are shown in Figure 3; platinum on graphite nanostructures are shown in Figures 4 and 5. Surface structures may be refined by low energy ion beam sputtering (IBS). We find that IBS can be used as a shaping tool of self-assembled nanostructures by reducing the size down to 2 nm in a controllable manner. Ion-induced formation of nanostructures of unique shapes was correlated to ion-induced island diffusion on weakly interacting substrates.

Electronic properties and composition of the surfaces are probed by photoemission and the reactivity of the samples is studied by adsorption and desorption of simple gases to obtain information on size effects in the nanometer regime.

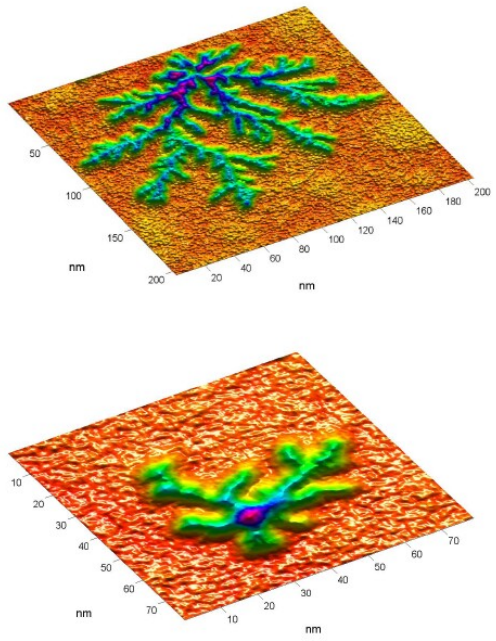

Figure 5. Colorized SEM images of Pt/C before (top) and after (bottom) down-scaling by ion beam sputtering.

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*)

Our research is centered on nanostructured soft matter, with an emphasis on polymeric systems. As a continuation of previous work on polymers with embedded nanoparticles, we have recently investigated new polymer-based matrices where nanodisks in the form of clay particles are introduced before commencement of in-situ polymerization of the monomer. The nanoparticles are surface treated with organic molecules in order to properly be integrated into the polymer matrix and thus maintain an exfoliated state. The particles may furthermore be aligned by imposing an electric field during the polymerization. The addition of these nanoparticles is shown to modify the mechanical properties of the polymer material, as well as the resistance to high temperatures.

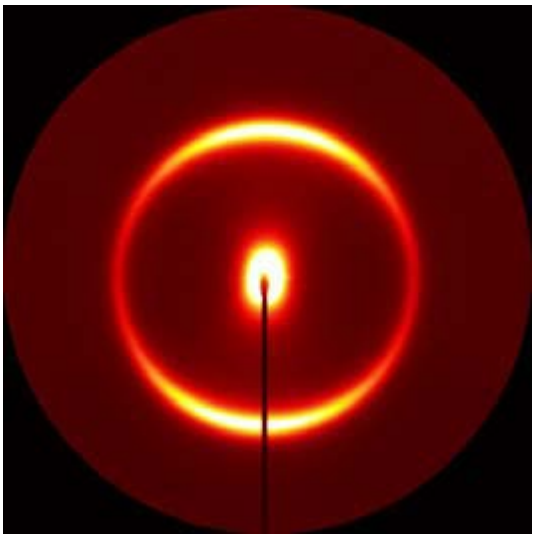

Figure 6. Scattering pattern of a PS-fluorohectorite system with aligned nanoparticles. (H. Mauroy)

In order to gain information on the nanostructure of these 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.

Electro-kinetic flow phenomena in micro- and nanopores

(*P. Berg*)

Our group studies the dynamics of electrolytes and, in particular, whether continuum models can be applied to describe their underlying physical processes, both at thermodynamic equilibrium and in non-equilibrium settings.

Recent advances in the development of electro-chemical energy devices such as fuel cells, batteries and super-capacitors, have led to a renewed interest in such mean-field models. These can be especially useful when capturing the corresponding flow phenomena of ionic solutions in micro- and nanopores, and relating these to data measured experimentally.

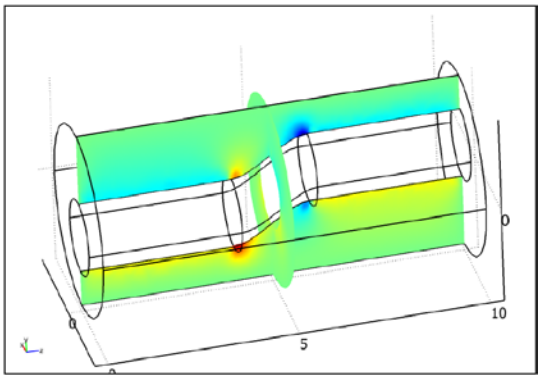

Figure 7. Flow of water and protons through a soft PEM nanopore.

The main focus lies on electro-diffusion in polymer electrolyte membranes (PEM) and catalyst layers, as used in PEM fuel cells. Both reactive and non-reactive flows are of interest, including their interplay with the pore morphology.

We seek consistent thermodynamic formulations that incorporate solvation phenomena and non-uniform permittivity. The derivation of mean-field models entails the computation of correlation functions, free energies and discrete lattice dynamics.

This work is conducted in collaboration with Professor Michael Eikerling at Simon Fraser University, Canada, and Dr. Markus Schmuck at Imperial College, UK.

SECTION OF CONDENSED MATTER PHYSICS

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Assoc. professor Antonius van Helvoort
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Postdoc. Ragnhild Sæterli
Postdoc. Dung Trung Tran
Postdoc. Lars-Erik Walle
Research Scientist Flemming F.J. Ehlers

Overview

The research activities are within experimental condensed matter physics, with particular emphasis on advanced characterization methods for studying physical properties of materials and material structures. The division consists of the transmission electron microscopy (TEM), X-ray, and scanning tunnelling microscopy (STM) groups. The two former groups enjoy status as national resource centres. A large fraction of the research is focused on nanoscale structure studies and the connection to macroscopic physical properties. An increasing part of the activities is directed towards numerical simulations and modelling of both the materials systems and the characterization experiments. Here, a brief survey of the three research groups is given. At the end an example of a current research project is described in more detail.

Survey of research activities

Transmission electron microscopy (TEM)

(R. Holmestad, A.T.J. van Helvoort, J. Walmsley, B.G. Soleim, R. Bjørge, F.J.H. Ehlers, R. Sæterli, T.Tran)

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 at the end of 2012 eight PhD students and four post-docs, and works in close collaboration with SINTEF through the TEM Gemini centre (see http://www.ntnu.edu/geminicentre/tem).

In 2012 the TEM Gemini centre was involved in 38 journal publications, of which 27 with at least one co-author from the Division of Condensed Matter. The group educated 2 PhD students; Roya Dehghan-Niri (catalysts) and Jelena Todorovic (III/V Nanowires). One new PhD project within aluminium alloys was started up in 2012. Four Master students finished their degree successfully within TEM and we offered an intensive TEM introduction course with ten participants. In June we organized the ICPMAT conference with 55 participants from 8 countries. We have organized group meetings almost every week, and have given many guided tours for high school students to the microscopes.

In May 2012 the nationally coordinated NORTEM project between NTNU, UiO and SINTEF signed contracts with TEM manufacturers for five new TEMs to Oslo and Trondheim. NORTEM is a large scale infrastructure project which was granted 58 MNOK from the Research Council of Norway and 21 MNOK from the three partner institutions to realize this major upgrade and extension. In Trondheim three new TEMs will be installed: i) a state-of-the-art double corrected instrument with cold field emission source, ii) a modern field emission TEM and iii) an easy-accessible TEM with a thermionic source.

In autumn 2012 rebuilding started in the basement of Kjemiblokk I close to NTNU NanoLab to host these machines. The top machine will be placed in a special conditioned room with water cooled walls and field-cancellation system to guarantee down to sub-Å resolution. In 2013 all three machines will be installed and become operative.

Figure 1. Antonius van Helvoort at the JEOL 2010F. This microscope is used for research and teaching. Photo: Terje Trobe.

The group has for many years worked with SINTEF and Hydro on alloy development and nucleation of precipitates in aluminium alloys, including structure determination of metastable hardening phases by combining experiments (high resolution TEM, scanning TEM, quantitative diffraction and atom probe) and modelling (density functional theory). In addition, there is a broad range of research activities 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
- Functional perovskite materials - ferroelectric thin films and nanorods
- Nanoparticles and support in catalyst materials – electron tomography and in situ techniques
- Nanowires of III-V semiconductors
- Intermediate band solar cell materials
- TEM/STEM image simulations and quantification.

Experimental Surface Science

(A. Borg, E. Wahlström, J.W. Wells, L.-E. Walle)

The scanning tunnelling microscopy group has two major lines of research activities primarily based on the scanning tunnelling microscopy (STM) instruments in the department, namely nano-magnetics 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 2012 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 and Div. of Synchrotron Radiation Research at Lund University (Prof. E. Lundgren and assoc. prof. J. Gustafson). Another main topic has been to understand the adsorption behaviour and interaction of selected adsorbates with ordered TiO_2 surfaces as well growth behaviour of chemical vapour deposited TiO_x thin films on metal substrates, where we collaborate closely with Dept. of Physics and Astronomy at Uppsala University (Prof. A. Sandell) and Dept. Chemical Physics at Lund University (Prof. P. Uvdal). A third line of activities has been directed to determining the stoichiometry of ultrathin $La_{1x}Sr_xMnO_3$ (LSMO) and $BiFe_{0.5}Mn_{0.5}O_3$ films. A new research area, understanding electronic properties of quantum confined doped materials, has also been initiated. In particular, nanoscale confinement in topological insulators and traditional semiconductors garner much interest for their role in quantum computation applications. Conductivity measurements, band-structure measurements and DFT calculations are performed with collaborators in Aarhus, Lund and Sydney.

Our experimental approaches have included STM and high-resolution photoelectron spectroscopy (HRPES), angle-resolved photoemission spectroscopy (ARPES), as well as near ambient pressure X-ray photoelectron spectroscopy (HPXPS). The HRPES, ARPES and HPXPS studies were performed at the MAX IV Laboratory, in Lund, Sweden and at ASTRID in Aarhus, Denmark. The experimental work is complemented with density functional theory calculations performed by collaborating groups in Sweden (Assoc. prof. H. Grönbeck, Chalmers University of Technology in Göteborg, and prof. N. Skorodumova, Royal Institute of Technology in Stockholm) and Australia (Dr. O. Warsckow). Specific projects have been:

- Oxidation and reduction behaviour of (100)-oriented single crystal surfaces of PdAg and PdCu.
- Near ambient pressure XPS studies of Pd-based catalytic model systems.
- Adsorption and dissociation behaviour of water on rutile surfaces.
- Formation of thin TiO_x films by chemical vapour deposition on gold single crystal surfaces and their interaction with water and atomic hydrogen.
- Photoelectron spectroscopy studies of $La_{0.67}Sr_{0.33}MnO_3$ and $BiFe_{0.5}Mn_{0.5}O_3$ interfaces.
- Formation of graphite/graphene films through Fe assisted growth on SiC and diamond.
- Bandstructure and conductivity measurements of quantum confined dopant layers in silicon and Bi_2Se_3.

Experimental Nanomagnetics

The research on nanomagnetics is dedicated to understanding the physics of magnetic structures and magnetodynamics at the nanoscale. In particular STM-based transport measurements in combination with ferromagnetic resonance measurements are utilized to understand how charge and spin currents within materials interplay with magnetic material. A main line of research is performed in conjunction with the Department of Electronics and Telecommunications (Prof. T. Tybell) to study functional metal oxides. In addition to this we have active collaborations with groups in Sweden (Ass. Prof. R. Mathieu, Uppsala, Prof. Maj Hansson, Göteborg), and USA (Prof. Andrew Kent, New York) where a longer sabbatical period was spent in 2012. The specific activities during the last year has been along the following lines:

- Magnetodynamic and transport properties of LSMO and heterostructures of LSMO/LMO.
- Investigation of model systems (Fe and Bi on graphite) in preparation for current induced magnetization reversal through laterally resolved point contact studies of interface resistance.
- Set up of low temperature FMR characterization (utilizing EPR and waveguide set-up).

X-ray scattering, diffraction and imaging

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

The X-ray group is active in applying and further developing X-ray scattering and imaging methods for studying materials ranging from functional polymers for organic electronics, via oxides and metallic nano- and microstructured materials. In 2012 the group has continued and expanded its activities within national and European research projects, and enjoys close collaboration with several world-leading groups both in X-ray physics and in materials science. The group currently has two post docs, four PhD students and several project and master students. Significant upgrades have been done in the X-ray laboratory, in connection with its new status as a national resource centre, RECX. Presently, it consists of four set ups, two of which are used for X-ray scattering and diffraction experiments, and a third is dedicated to microradiographic imaging. The fourth instrument, a versatile tomography instrument from Nikon for 3D imaging, was installed in March 2013. 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, mainly at ESRF (Grenoble), HASYLAB (Hamburg) and SLS (Zurich).

Current research activities include:

- Coherent X-ray diffractive imaging, carried out in close collaboration with the Swiss Light Source. We are involved in both methods development and material physics experiments on samples ranging from nanoparticles to organic fibres.
- Raster scanning WAXS and SAXS measurements of thin films and fibres.
- Studies of catalytic nanoparticles under working conditions by small-angle X-ray scattering (SAXS)
- Grazing-incidence small- and wide angle X-ray scattering (GISAXS / GIWAXS), with a special emphasis on modelling (in-house software developments *SimDiffraction*). We employ these techniques mainly for clarifying structure-property relations in conjugated polymers and liquid crystals, mainly for organic electronics.
- 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.
- Recrystallization kinetics in ultra-fine grained metals.

Research example: Controlled graphene formation on semiconductors

(E. Wahlström, D.W. Breiby, K. Høydalsvik, F. Song, J.W. Wells)

Graphene has excited much interest for its novel mechanical and electronic properties, and hence has been proposed as an ideal material for a wide range of applications. In order to capitalise on this, it is necessary to manipulate its growth in an industrially realistic manner. Poorly conducting substrates are also necessary if the electrical properties are to be utilised.

In this project, we developed a method for growth on diamond and SiC at moderate temperatures, by making use of a chemical intermediate (in this case $Fe/FeSi_x$). Not only does this allow graphene-on-semiconductor formation at industrially realistic temperatures, the thickness and lateral distribution can be controlled by standard lithographies of the intermediate.

A wide range of experimental techniques (XPS, STM, ARPES and X-ray diffraction) was used to understand the complex chemistry, structure and electronic properties of substrate, intermediate and graphitic layer. As an example we display the carbon XPS spectra (fig. ??.a), and the dependence of graphite formation on the amount of Fe deposited. The quality of the graphene formed was also assessed through X-ray diffraction and scanning STM the latter which confirms the grapheme honeycomb structure (fig. ??b.). We also performed an analysis of the electron structure through ARPES of the grapheme overlayers, revealing the characteristic pi-band reaching a Dirac-point at $\overline{K}$ (Fig ??c). First results were published in Carbon, and further studies on patterned graphene formation through lithography of the intermediate layer are ongoing.

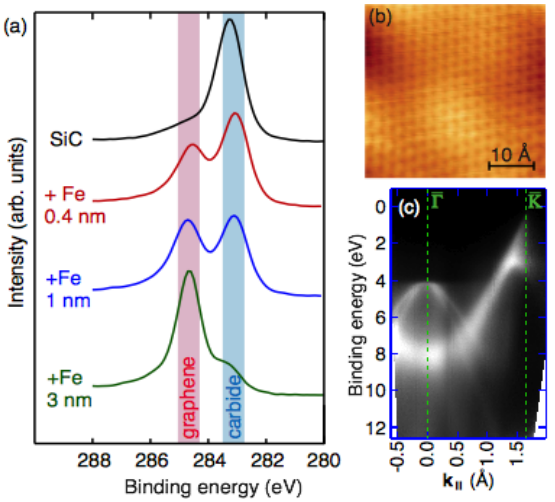

Figure 2: (a) XPS measurements of the carbide to graphene reaction, showing its dependence on the initial Fe quantity. (b) STM image of the graphene layer formed and (c) ARPES measurement showing the bandstructure of the graphene with its characteristic pi-band reaching a Dirac-point at $\overline{K}$.

SECTION OF THEORETICAL PHYSICS

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Assoc. professor Ingjald Øverbø
Adjunct professor Roger Sollie

Research staff
Postdoc. Alireza Qaiumzadeh
Research scientist Sergey Ostapchenko

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

Transport of spin and charge in nanostructures *(A. Brataas, A. Qaiumzadeh, S. Sadjina, A. Kapelrud, E. Tveten, H. Skarsvåg*)
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, magnetization dynamics 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 antiferromagnets, ferromagnets, magnetic insulators, 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) magnetization dissipation in ferromagnets and magnetic insulators, 5) quantum computing with spins in quantum dots. We published 6 papers in 2012, among which one in Nature Materials, three in Physical Review Letters, and two in Physical Review B.

Quantum transport and quantum phase transition *(A. Sudbø, I. B. Sperstad, E. B. Stiansen, E. Herland, H. Enoksen, J. Linder)*
Unconventional novel materials open the possibility of studying low-energy states, with unusual electronic properties in a precise manner experimentally as well as theoretically. Examples of such materials strongly correlated fermion systems exhibiting unconventional superconductivity, multicomponent Bose-Einstein condensates, non-Abelian fractional quantum Hall states, as well as novel combinations of ferromagnetic and spin-triple superconducting states. 1) Strongly correlated systems: We have performed large-scale quantum Monte Carlo simulations on a 2+1-dimensional dissipative quantum rotor model to both with compact and noncompact phases, to investigate the phase-structure of such models as the strength of dissipation is varied. We find a rich phase-structure continaing fully ordered, partially ordered, and fully disordered phases. In particular, we find one novel type of quantum phase transition directly from the fully order to the fully disordered phase. 2) Multicomponent condensates: We have investigated novel types phases and phase-transitions in unconventional multi-compnent plasmas pertinent to both multicomponent Bose-Einstein condensates and non-Abelian fractional Quantum Hall states. The latter results have ramifications for the entanglement of such states and their possible applications in quantum computing. We have published 5 papers on these topics in Physical Review B and Rapid Communications.

Quantum transport and magnetization dynamics
(*J. Linder, M. Alidoust, I. Kulagina, D. Toniolo*)
During 2012 we published 4 papers in Physical Review B and 2 papers in Physical Review Letters. One of the papers were chosen as Editors' Suggestions. The primary research focus has been to investigate the interplay between quantum transport and magnetization dynamics 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.
Some research highlights from the above publications include the prediction of unusual magnetic interference patterns in inhomogeneous Josephson junctions, which are consistent with recent experimental observations. We have also demonstrated how current-induced and magnonic spin-transfer torques may conspire to produce termination and reversal of domain-wall motion in magnetic

nanowires. The spin-transfer torque in ferromagnetic superconductors, both via spin-injection and as an equilibrium effect between two superconductors has been shown to depend on the internal U(1) phases of the two spin-condensates, giving rise to different torques even in the case of phase-locking to 0 or pi. Analytical expression for these spin-transfer and exchange torques have been derived.

Astroparticle physics
(L. Dal, G. Giacinti, M. Kachelriess, S. Ostapchenko et al.)
Our research has concentrated on the intersection between cosmic ray physics and searches for physics beyond the standard model of particle physics. The latter requires a precise understanding of astrophysical "backgrounds," while the former aims at an understanding of the astrophysical processes leading to high energy particles.
An example illustrating well this interplay is the indirect search for dark matter (DM) using antimatter. The annihilation of DM leads to equal injection rates of matter and antimatter particles into the Galaxy, while the cosmic ray flux from astrophysical sources is matter-dominated. A possible way to detect DM is therefore to carefully estimate the expected antimatter fluxes from astrophysical sources, and then search for any excess. We continued our investigations, if (re-) acceleration of secondaries in supernova remnants can lead to an enhancement of antimatter fluxes in the Milky Way. In particular, we calculate the diffuse intensity of cosmic ray nuclei and their secondaries in the Boron-Carbon group produced by supernova remnants. Our prediction that supernova remnants cannot be the source of enhanced antimatter fluxes at high energies can be tested soon with the data of the AMS-02 experiment on board of the International Space Station. Another possible signature of dark matter that can be tested by the AMS-02 experiment is antideuterons. As deuteron production depends on momentum differences between the coalescencing nucleons, it is potentially very sensitive to the hadronization model employed. We studied this dependence using two different hadronization models and showed that it is small compared to the astrophysical uncertainties.
We continued also our studies of the propagation of high energy cosmic rays in magnetic fields. After having showed that the diffusion of protons is anisotropic on scales smaller than the coherence length even for a pure isotropic random field, we have extended these studies to electrons which suffer from energy losses. We showed that for the observation of gamma-ray images of cosmic ray sources these energy losses play no important role.
We started studies to derive the energy spectrum of Galactic cosmic ray outside the Solar system using gamma-ray observations. We showed that the spectral shape of cosmic rays follows as expected a power-law in momentum, while adding a break around 3 GeV improves further the agreement in the energy range 0.2-3 GeV. A code for the calculation of proton-proton fragmentation functions has been made publicly available. While we continue these studies with parts of the Fermi-LAT collaboration, it is interesting to note that the particle physics uncertainties in this problem are larger that the astrophysical ones.

Studies of entanglement
(*J. Myrheim, L. O. Hansen, A. Hauge, Ø. S. Garberg*)
Entanglement in mixed quantum states is studied from a geometric point of view.

Fermionic formulation of some colouring problems
(J. O. Fjærestad, F. T. Prinz)
We have studied some colouring problems which can also be thought of as particular generalizations of classical dimer models. We have developed a fermionic formulation of these problems in which the partition function (number of colourings) can be expressed in terms of Grassmann integrals involving a quartic action. The Grassmann integrals can be exactly evaluated numerically, which has been explicitly done for the square lattice. We are working to apply the formalism to other lattices of interest.

Casimir friction
(J.S. Høye, I. Brevik)
We have extended our study of Casimir friction from a pair of dielectric particles to parallel plates moving parallel to each other without direct contact. Again we use the statistical mechanical method combined with the Kubo formalism for the response due to a perturbing interaction. We obtain explicit numerical results. However, we find the friction force so small that it is mainly of academic interest. The reason is that thermal energies like 25 meV is almost unable to excite surface plasma waves whose energy quanta for gold are about 6 eV.

Critical properties of D-dimensional spins
(J. S. Høye, E. Lomba)
Earlier we analysed the critical properties of the HRT (hierarchical reference theory) in view of the SCOZA (self-consistent Ornstein-Zernike approximation). We found simple rational numbers for the critical indices. These results were supported by accurate numerical solutions of the HRT equation. By additional arguments it is not ruled out that these indices (except for logaritmic type corrections) are the exact ones for real systems. We have found a way to extend the HRT to D-dimensional spins, i.e. spin dimensionality is D while the spatial dimension is still 3. This more general situation is investigated both analytically and numerically.

Corrections from radiation to van der Waals forces.

(J.S. Høye, M.H. Waage)

When retardation effects or radiation is neglected in the electromagnetic interaction between dielectric particles the induced Casimir interaction between pairs of particles becomes the well known attractive $1/r^6$ van der Waals interaction. The influence of radiation, related to the Lamb shift of atoms, is thus well known for a pair of particles. We extend this to a fluid of particles at arbitrary density by combining statistical mechanical methods, developed earlier for classical and quantized dielectric fluids. In this way we have been able to take into account in a quantitative way the particle structure of a many-body interacting system with time dependent interactions. Earlier one of us has included the Casimir and van der Waals interactions in a consistent way in the usual methods used for ab initio quantum mechanical evaluations of molecular energies due to their electrons. In this respect the dielectric fluid may be regarded as a strongly simplified model of the electron "fluid" of a large molecule.

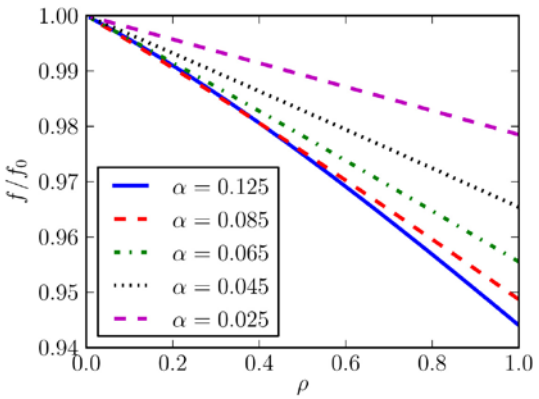


Figure 1. Induced van der Waals energy per particle f relative to its low density value f_0 from direct sum of independent particle pairs. The $\rho R^3 \rightarrow \rho$ is dimensionless particle density where R is molecular hard core diameter and $\alpha/R^3 \rightarrow \alpha$ is dimensionless polarizability (in Gaussian units).

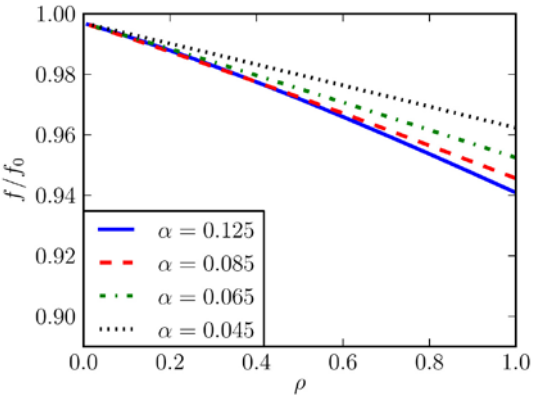


Figure 2. Induced Casimir energy per particle f as a function of ρ for various α. The curves are all for $\lambda = 2\pi c/(\omega_0 R) = 100$. The λ is the wavelength of electromagnetic radiation relative to R. The ω_0 is the (angular) eigenfrequency of the oscillating dipole moments of molecules.

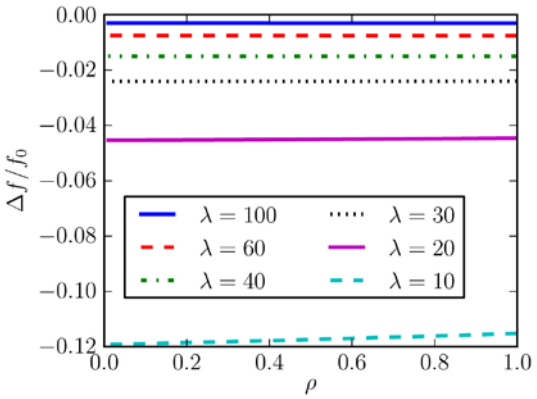


Figure 3. The difference Δf between the Casimir energy of Fig. 2 and the van der Waals energy of Fig. 1 relative to f_0 as function of ρ for various λ and polarizability α= 0.075. A stricking feature is that $\Delta f/f_0$ is almost independent of ρ.

Copper nanoparticles

(*T. Kristiansen, K. Mathisen, J. A. Støvneng*)

Copper nanoparticles have several applications within catalysis. Particle size and morphology are influenced by the conditions during synthesis, such as temperature and type of silica support. Model Cu_{80} clusters are optimized with DFT calculations. Comparison of EXAFS spectra, based on experimental and model nanoparticles, suggests the presence of both fcc- and bcc-like particles. The example shown below results in a rather broad distribution of Cu-Cu nearest neighbor distances, which is observed for some of the synthesized particles (Fig. 4). (T. Kristiansen et al, *J Phys Chem C* **116**, 20368 (2012)).

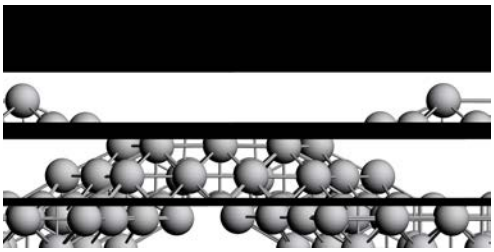


Figure 4. Model Cu_{80} cluster with D_{2h} symmetry and bcc-like crystal structure.

QCD Phase Diagram

(J. O. Andersen, R. Khan, and A. Amador)

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.

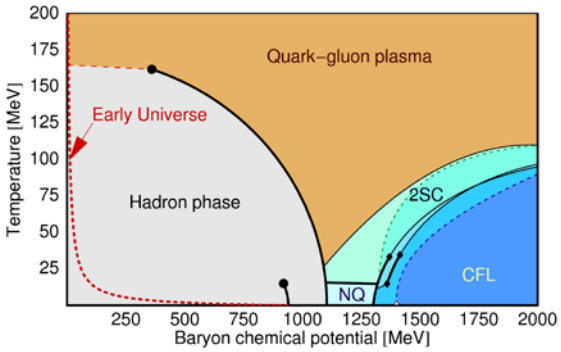


Figure. 5. QCD phase diagram as function of baryon chemical potential and temperature.

We are currently investigating the chiral and deconfinement transitions in very strong magnetic field. This is a part of the ongoing research done in our group to unravel the properties of strongly interacting matter in extreme conditions. Matter in very strong magnetic field is relevant in a number of situations. For example, strong magnetic fields are present in certain neutron and quark stars. The equation of state is strongly affected by the presence of strong B field and hence the properties of the stars as well. Strong B fields are also present in noncentral heavy collisions and so it is important to investigate the properties of matter in this context. Finally, we started a project with international collaborators to calculate quark susceptibilities for hot matter. This is of great interest to the lattice community in order to determine the equation of state at finite baryon chemical potential. The group published four papers, two in JHEP, and two in Physical Review D, and has two preprints.

Estimating coefficients of Frobenius series

(A. Noreen, K. Olaussen)

Sometimes the solutions of the common (or not-so-common) differential equations occurring in mathematical physics can profitably be expanded in Frobenius series around a given point. With knowledge of the differential equation it is also straightforward to make analytic continuation of such series, i.e. change the point of expansion. An optimal evaluation strategy requires some prior knowledge about the coefficients in the series. We have found that surprisingly accurate information about the absolute value of the coefficients can be obtained from WKB estimates of the solution, in combination with a Legendre transform.

Resummed loop expansion and exact results

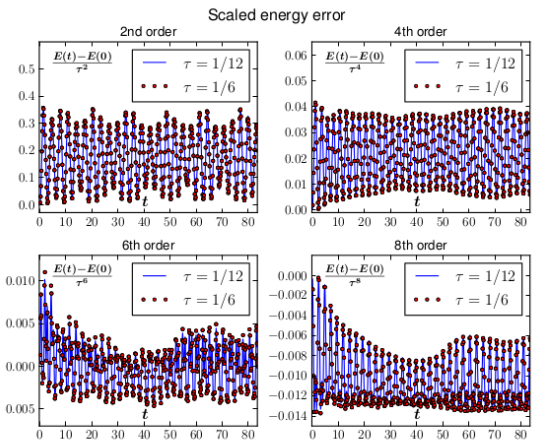
(A. Noreen, K. Olaussen)

The loop expansion is formally an expansion in Planck's constant *h*, similar to the WKB expansion. We have investigated the latter in a simple model, to order 1704 in *h* for the energy eigenvalues. The series is badly divergent, but can be massaged into a Borel type integral, where the integrand can be represented by apparently convergent series over the full integration range. Nevertheless this integral representation does not reproduce the exact result, even in the absence of any visible source of non-perturbative contributions.

Higher order symplectic integrators for the Hamilton equations

(A. Mushtaq, A. Kværnø, K. Olaussen)

The differential equations of Hamiltonian mechanics preserve the symplectic structure of phase space (as f.i. defined by the Poission bracket). It is possibly to construct numerical integration routines which preserve this structure exactly. One way is to split the motion into an iterated sequence of *kicks* (changing momenta but not positions, as generated by a Hamiltonian $H = V$) and *steps* (changing positions but not momenta, as generated by a Hamiltonian $H = T$). This is sometimes referred to as the Størmer-Verlet method, but the method was already used by Newton. We have constructed, implemented and tested higher order (in accuracy) extensions of this method. For a given $H = T + V$, we use an effective potential energy *Veff* to generate the kicks, and an effective kinetic energy *Teff* to generate the steps (the latter must in general be accompanied by some more gentle *pushes).*



Energy conservation of the Störmer-Verlet and higher order symplectic integrators, tested on a Fermi-Pasta-Ulam-Tsingou type chain. The error does not increase with time.

Figure 6. Energy conservation by computations.

PUBLICATIONS

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(Total: 152)

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ELMAG: A Monte Carlo simulation of electromagnetic cascades on the extragalactic background light and in magnetic fields. *Computer Physics Communications* 2012 ;Volum 183.(4) s. 1036-1043

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Alidoust, Mohammad; Sewell, Granville; Linder, Jacob.
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Ellingsen, Pål Gunnar.
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Elster, Anne C.; Jensen, Rune Erlend; Nikolaisen, Ivar Ursin; Falch, Thomas Løfsgaard; Pakdel, Samira; Bozorgi, Mohammadmehdi; Smistad, Erik; Kvam, Johannes; Brende, Ole Martin; Pedersen, Stian Aaraas; Melhus, Lars Kirkholt; Nordhus, Lars Espen; Skomedal, Andreas; Nordahl, Andreas; Knutsen, Henrik.
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(Total: 8)

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Persson, Rolf Jonas.
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* University of Ottawa, Canada (A. Novruzi)

Brataas, A.:
* Harvard University, (Bertrand I. Halperin)
* UCLA, (Yaroslav Tserkovnyak) (USA)
* New York University, (Andrew D. Kent) (USA)

Breiby, D.W.:
* Georgia Institute of Technology, USA (J.-L. Bredas)

Davies, C.:
* Harvard Medical School Boston, USA (R.K. Jain Y. Boucher)
* Mount Sinai School of Medicine New York, (W.Mulder)

Espy, P.:
* Hampton University, Center for Atmospheric Sciences (James M. Russell III), Virginia, USA

Fossum, J.O.:
* PUC Rio de Janeiro Brazil (Prof. Marcio Carvalho)
* Universidade Federal de Pernambuco, UFPE, Recife, Brazil (Profs. Wilson Barros and Mario Engelsberg)
* UFABC, Sao Paulo, Brazil (Prof. Roosevelt Droppa)
* University of Brasilia, UnB, Brasilia, Brazil (Prof. Geraldo Jose da Silva)
* University of Sao Paulo-USP (Prof. Antonio Figueredo),
*University Havana, Cuba (Profs. Ernesto Altshuler and Aramis Rivera)

Gibson, U.:
* Dartmouth College, Hanover NH USA (J. J. BelBruno)
* IBM Burlington, VT USA (M.L. Lipson)
* Univ. Arkansas, Little Rock AK USA (J. B. Cui)

Hansen, A.:
* Univesidade Federal do Céara, Fortaleza, Brazil (Soares)

Holmestad, R.
* University of Illinois, Urbana-Champaign, USA (JM. Zuo)

Høye, J.S.:
* Oklahoma University, Norman, Oklahoma, USA (K. A. Milton), Theoretical Physics

Linder, J.:
* Michelson Lab, Physics Division, Naval Air Warfare Center, China Lake, California

Reenaas, T.W.:
* University of Edmonton, Canada (Ying Tsui) Department of Electrical & Computer Engineering

Skagerstam, B.-S.:
* Universidade Federal do Rio de Janeiro, Departamento de Fisica Matematica - Instituto de Fisica, Rio de Janeiro, Brazil (Prof. Ruynet Lima de Matos Filho et al.)
* Universidade Federal do Ceará, Departamento de Física, Fortaleza, Brazil. (Prof. José Soares de Andrade Junior)
* University of Florida, USA (J.R. Klauder)
* Syracuse University, N.Y., USA (A.P. Balachandran).
* Departamento de F´ısica, Universidade Federal do Cear´a, Brazil (R.N. Costa Filho)
* Universidade Estadual do Cear´a, Faculdade de Educa¸, Brazil (G Alencar)

Stokke, B.T.
* Albert Einstein College of Medicine, New York, USA (C F Brewer)
* Case Western Reserve University School of Medicine, Cleveland, Ohio, USA (T A Gerken)

Sudbø, A.:
* Department of physics, University of Massachussets at Amherst, Massachusetts, USA (prof. E. Babaev)
* Department of physics, University of California at Riverside, USA (prof. C. M. Varma).
*University of Colorado at Boulder, USA (profs. L. Radzihovsky and V. Gurarie)
* Kavli Institute of Theoretical Physics, University of California at Santa Barbara, USA (prof. C. Nayak)
* Station Q, Santa Barbara, USA (dr. P. Bonderson)

Wahlström, E.:
* New York University (prof. Andy Kent).
* Brookhaven National Laboratory (Dario Arena)

ASIA

Brataas, A.:
* Tohoku University, Sendai, Japan (Gerrit E. W. Bauer)

Fossum, J.O.:
* Gwangju Institute of Science and Technology, South Korea (Prof. Do Young Noh)

Hansen, A.:
* Institute of Mathematical Sciences, Chennai, India (Ray)
* Saha Institute of Nuclear Physics, Kolkata, India (Chakrabarti).

Holmestad, R.
* Tokyo Technical University (T. Sato)
* Toyama University (S.Ikeno, K. Matsuda, S. Nishimura)

Linder, J.:
* Department of Physics, Tokyo Institute of Technology, Japan (T. Yokoyama)
* Department of Applied Physics, Nagoya University, Japan (Y. Tanaka)

Lindgren, M.:
* Riken Institute, Wako, Saitama, Japan (Dr. Tamotsu Zako)

Reenaas, T.W.:
* Multimedia University, Malaysia (Teck Yong Tou)

Sikorski, P.:
* Department of Biomaterials Sciences, Graduate School of Agricultural and Life Sciences, The University of Tokyo, Japan. (Dr. M. Wada). Biophysics

Skagerstam, B.-S.:
* Centre for High Energy Physics, Indian Institute of Science, Bangalore, India (S. Vaidya).

Stokke, B.T.:
* Osaka Prefecture Univ., Osaka, Japan (S. Kitamura), Biophysics
* Department of Polymer Chemistry, Graduate School of Engineering, Kyoto University, Katsura Nishikyo-ku, Kyoto 615-8510 Japan (Kazunari Akiyoshi) Biophysics

Sudbø, A:
* Department of Applied Physics, Nagoya University, Japan.
* Department of physics, University of Tokyo, Japan (prof. N. Nagaosa).

Wahlström, E:
* The Key Laboratory for Magnetism and Magnetic Materials of Ministry of Education Lanzhou University (D.Z . Yang)

AUSTRALIA

Davies, C.:
* Cancer Biology Laboratory, Peter Mac Callum Cancer Centre, Melbourne (Robin Anderson)

van Helvoort, A.T.J.:
* Monash University, Melbourne, Australia (J. Etheridge)

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

OSEANIA

Skagerstam, B.-S.:
* Department of Physics, University of Auckland, New Zealand (S. Parkins)

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. Bruland, A. Skretting, D.R. Olsen)
* Statoil Research Centre, Trondheim (F. Antonsen, H. Widerøe, Erling Rytter)
* 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)
* University of Bergen (J.Stamnes, P. Osland)
* 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
* Finnmark University College (Bjørn Tore Esjeholm)
* Numerical Rocks AS, Trondheim (Ramstad, Øren)
* Høgskolen I Sør-Trøndelag, HiST (E. Munkeby)
* Vestfold University College (K.E. Aasmundtveit
* The Norwegian Polar Institute, (Kim Holmén), Tromsø Norway.
* Dept of Circulation and Medical Imaging, NTNU (Prof. Bjørn Angelsen, Prof Olav Haraldseth)
* Epitarget as (Sigrid Fossheim)
* Department of Oncology, St.Olav's Hospital (T. Strickert, J. Frengen)
* Høgskolen i Sør-Trøndelag, HIST (G. Oftedal, S. Ramstad)
* Institute of Neuroscience, St. Olav Hospital Norsk Lysteknisk komité
* Trondheim Science Centre
* SINTEF Energiforskning

* SINTEF Materials and Chemistry (R. Bredesen)
* SINTEF Petroleum Research (B. Bjørkvik, R.M. Holt)
* Sør-Trøndelag University College, Faculty of Technology (T.M. Thorseth)
* Sør-Trøndelag University College, Faculty of Teacher Education (E. Munkebye, K. Feren, J. Cyvin)
* Finnmark University College (D.A.Lysne, B.T. Esjeholm)
* Paper and Fiber Research Institute-PFI (G.Chinga)
* Molde University College, Molde (P.K. Rekdal)
* Norwegian Center for Stem Cell Research. Rikshospitalet. Oslo. (Prof. Jan E. Brinchma
* SINTEF Materials and Chemistry (Erik Andreassen
* Birkeland Centre for Space Sciences (University of Bergen, UNIS)
* Andøya Rocket Range (Michael Gausa)
* Norwegian Polar Institute (Kim Holmen)

EDUCATION

SUBJECTS AND STUDENT ATTENDANCE

Some subjects were self-study courses in 2012

Subjects		*Student Attendance*
MSc Technology 1st and 2nd year		
TFY4102	Physics for Product Design Engineering, Earth Sciences and Petroleum Engineering (incl. lab)	141
TFY4104	Physics for Product Design and Manufacturing, Marine Technology (incl. lab)	246
TFY4106	Physics for Civil and Transport Engineering, Industrial Economics and Technology Management (incl. lab)	198
TFY4108	Physics for Energy and Environmental Engineering (incl. lab)	116
TFY4115	Physics for Electronics Engineering, Engineering Cybernetics, Nanotechnology (incl. lab)	170
TFY4120	Physics for Chemical Engineering and Biotechnology, Materials Science and Engineering (incl. lab)	119
TFY4125	Physics for Computer Science, Communication Technology	213
TFY4145	Mechanical Physics (incl. lab)	127
TFY4155	Electromagnetism (incl. lab)	107
TFY4160	Wave Physics (incl. lab)	91
TFY4165	Thermal Physics (incl. lab)	97
TFY4215	Introduction to Quantum Physics	106
TFY4335	Nano Life Science	36
MSc Technology 3rd year		
TFY4170	Physics 2 for Electronics Engineering	47
TFY4185	Measurement Techniques (incl. lab)	89
TFY4190	Instrumentation (incl. lab)	50
TFY4195	Optics (incl. lab)	55
TFY4205	Quantum Mechanics II	27
TFY4230	Statistical Physics	60
TFY4240	Electromagnetic Theory	46
TFY4250	Quantum Mechanics I	54
TFY4260	Cell Biology and Cellular Biophysics (incl. lab)	29
MSc Technology 4th year		
TFY4200	Optics, Advanced Course (incl. lab)	4
TFY4210	Quantum Theory of Many-Particle Systems	21
TFY4220	Solid State Physics (incl. lab)	92
TFY4225	Nuclear and Radiation Physics (incl. lab)	40
TFY4235	Computational Physics	36
TFY4245	Solid State Physics, Advanced Course	26
TFY4255	Materials Physics (incl. lab)	12
TFY4275	Classical Transport Theory	12
TFY4280	Signal Processing (incl. lab)	12
TFY4292	Quantum Optics	10
TFY4300	Energy and Environmental Physics	67
TFY4305	Non-linear Dynamics	22
TFY4310	Molecular Biophysics (incl. lab)	9
TFY4315	Biophysics of Ionizing Radiation	12
TFY4320	Medical Physics (incl. lab)	10
TFY4340	Mesoscopic Physics	15
TFY4345	Classical Mechanics	35
TFY485x	Experts in Team, Interdisciplinary Project	49

MSc Technology 5th year

TFY4265	Biophysical Micromethods (incl. lab)	8
TFY4500	Biophysics, Specialization Project	10
TFY4505	Biophysics, Specialization Course	6
TFY4510	Physics, Specialization Project	31
TFY4515	Physics, Specialization Course	7
TFY4520	Nanotechnology, Specialization Project	14
TFY4525	Bionanotechnology, Specialization Course	11
TFY4900	Physics, Master's Thesis	30
TFY4905	Nanotechnology, Master's Thesis	4

BSc

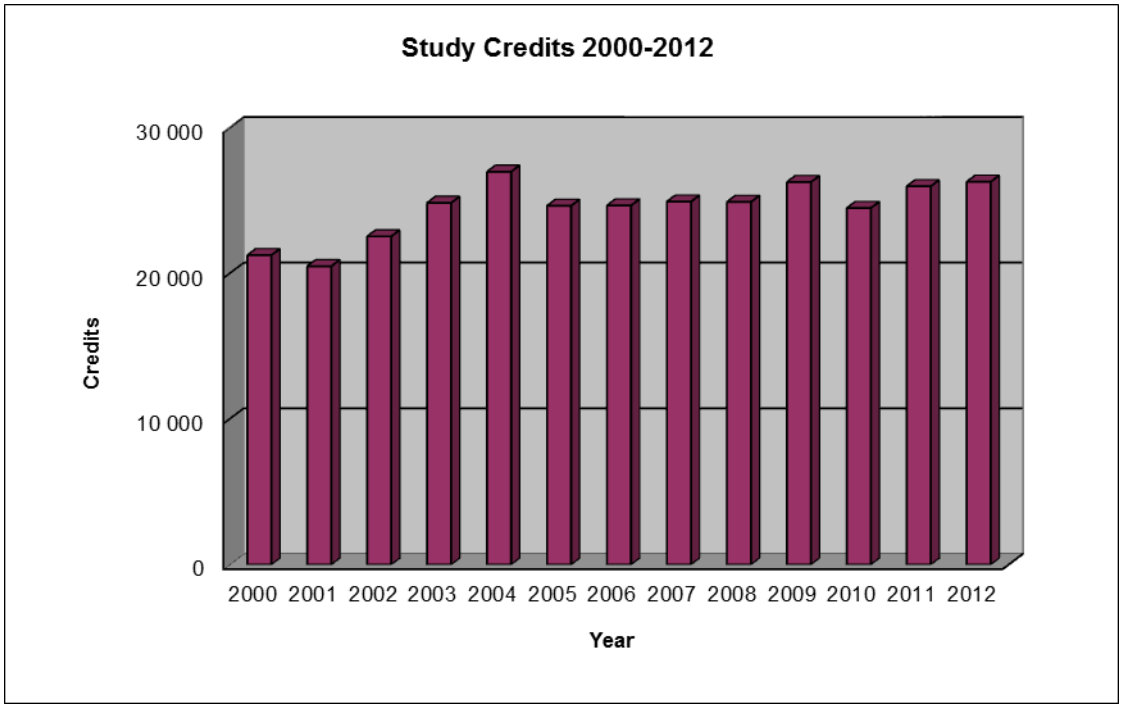
FY0001	Service Course in Physics (incl. lab)	46
FY1001	Mechanical Physics (incl. lab)	52
FY1002	Wave Physics (incl. lab)	45
FY1003	Electricity and Magnetism (incl. lab)	54
FY1005	Thermal Physics (incl. lab)	42
FY1006	Introduction to Quantum Physics	40
FY2045	Quantum Mechanics I	23
FY2302	Biophysics (incl. lab)	4
FY2450	Astrophysics	47
FY2800	Teacher Training/Dissemination Project in Physics	0
FY2900	Physics Education	0

MSc

RFEL3092	Research Methods in Science	10
FY2290	Energy Resources	19
FY3006	Sensors and Transducers	12
FY3114	Functional Materials	16
FY3201	Atmospheric Physics and Climate Change	18
FY3402	Subatomic Physics	21
FY3403	Particle Physics	25
FY3452	Gravitation and Cosmology	23
FY3464	Quantum Field Theory I	13
FY3466	Quantum Field Theory II	9
FY3900	Master Thesis in Physics	11
FY3950	Master Thesis in Physics (Teacher Education)	1

PhD

FY8100	Characterisation of Solid Surfaces	7
FY8102	Electron Microscopy and Diffraction	3
FY8104	Symmetry Groups in Physics	5
FY8201	Nanoparticle and Polymer Physics	2
FY8302	Quantum Theory of Solids	6
FY8303	Phase Transitions and Critical Phenomena	1
FY8304	Mathematical Approximation Methods in Physics	11
FY8305	Functional Integral Methods in Condensed Matter Physics	4
FY8407	Magnetic Resonance Imaging	4
FY8405	Radiation Therapy Physics	1
FY8502	Advanced Biophysics	4
FY8504	Advanced Experimental Physics	3
FY8902	Atmospheric Physics and Climate Change	1
FY8904	Computational Physics	12
FY8905	Materials Physics	2
FY8906	Biophysical Micromethods	2
FY8907	Classical Transport Theory	5
FY8908	Quantum Optics	1


Study Credits 2000-2012
30 000
20 000
10 000
0
Credits
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
Year

THESES – GRADUATE STUDIES

Master of Science in Technology – Applied Physics and Mathematics

Aas, Rune Øistein
"Electromagnetic Scattering. A Surface Integral Equation Formulation"
Supervisor: Simonsen, Ingve

Anmarkrud, Øystein Leines
"Swelling of Clay"
Supervisor: Fossum, Jon Otto

Benjaminsen, Bjørn Eirik
"Nanoflow of Protons and Water in Polymer Electrolyte Membranes"
Supervisor: Berg, Peter

Boayue, Nya Mehnwolo
"Nanomechanical characteristics of proteins and peptides in amyloid state based on AFM imaging"
Supervisor: Stokke, Bjørn Torger

Breisjøberg, Torjus
"Detection and Localization of High-Frequency Interception Signals using Compressive Sensing"
Supervisors: Hansen, Alex
Fredrik Hekland

Brønstad, Espen Stene
"Real-time Volume Rendering of 3D Echocardiographic Image Data on The GPU"
Supervisors: Lindmo, Tore
Hans Torp, Gabriel Kiss, Jon Åsen

Chapana, Randi Synnøve Hegdal
"Evidence of geomagnetic influence on the mesospheric circulation"
Supervisor: Hibbins, Robert Edward

Ervik, Åsmund
"The Local Level-Set Extraction Method for Robust Calculation of Geometric Quantities in the Level-Set Method"
Supervisor: Simonsen, Ingve

Fjær, Ingunn Grip
"Fire simulations and heatload to form the basis of safety assessment in oil and process industry"
Supervisors: Støvneng, Jon Andreas
Geir Berge

Garberg, Øyvind Steensgaard
"Positive partial transpose states in multipartite quantum systems"
Supervisor: Myrheim, Jan

Gislesen, Halvor
"Renormalised Intrinsic and Extrinsic Impurity Induced Spin-orbit Scattering in Graphene"
Supervisor: Brataas, Arne

Granholt, Jason Daniel David Andersen
"Phase transfomartion in a Al-Mg-Si alloy"
Supervisor: Holmestad, Randi

Hansen, Eirik Schrøder
"Numerical modelling of marine icing on offshore structures and vessels"
Supervisors: Simonsen, Ingve
Sigurd Henrik Teigen

Haugstad, Solveig Bjærum
"Ultrasound induced uptake of nanoparticles in cells"
Supervisor: Davies, Catharina de Lange

Henriksen, Lisa Grav
"Pump-probe experiments of multicrystalline silicon for solar cell applications"
Supervisors: Gibson, Ursula
Ulf Österberg

Hetland, Øyvind Storesund
"Atomistic Implications of Stacking Fault Energy on Dislocation - Void Interactions"
Supervisor: Simonsen, Ingve
Jon Samseth, Taira Okita

Hox, Kristian
"Experimental Studies of Instabilities Near the Sol-Gel Transition"
Supervisor: Fossum, Jon Otto

Håti, Armend Gazmeno
"Single molecule dynamic force spectroscopy of alginate-epimerase interactions using optical tweezers"
Supervisor: Sletmoen, Marit

Ingebretsen, Thomas
"System Identification of Unmanned Aerial Vehicles"
Supervisor: Simonsen, Ingve
Thor Inge Fossen

Karlsen, Terje Kultom
"Gold and Platinum Surface Nanostructures on Highly Oriented Pyrolytic Graphite"
Supervisor: Raaen, Steinar
Julukian Armen

Kittang, Lars Oskar Osnes
"Development and testing of a Linnik Interference Microscope for Sub-surface Inspection of Silicon during moving Indentation"
Supervisor: Kildemo, Morten
Lars Johnsen

Kjerstad, Knut Brøndbo
"Clay-oil droplet suspensions in electric field"
Supervisor: Fossum, Jon Otto

Lutro, Henrik Fahre
"The Effect of Thermophoresis on the Particle Deposition on a Cylinder"
Supervisor: Støvneng, Jon Andreas
Nils Erland Haugen

Marthinsen, Eirik
"Modellering av Termisk Stråling for Bruk i Brannsimuleringer. En teoretisk analyse og studie av noen aspekter"
Supervisor: Simonsen, Ingve
Geir Berge

Meyer, Karsten
"On the design of accurate spatial and temporal temperature measurements in sea ice"
Supervisor: Wahlstrøm, Erik
Knut Vilhelm Høyland

Næss, Live Nova
"Structure, composition and application of Pd based membranes for hydrogen technology"
Supervisor: Borg, Anne
Hilde Johnsen Venvik

Pedersen, Brede Dille
"Karakterisering av fluorescensspektra til nye nanopartikler for deteksjon av Alzheimers ved bruk av multifotonmikroskopi"
Supervisor: Lindgren, Mikael

Persvik, Øyvind Othar Aunet
"Non-destructive Evaluation of Stress and Fatigue Damage in Welded Carbon Steel Specimens Using Ferrx Electromagnetic Method (FEMM)"
Supervisor: Simonsen, Ingve
Harald Horn, Hans J. Roven

Romijn, Elisabeth Inge
"Development of 3-D quantitative analysis of multi-photon microscopy images"
Supervisor: Lilledahl, Magnus Borstad

Rustenberg, Karin Hveding
"X-ray Studies of Capture, Storage and Release of CO2"
Supervisor: Fossum, Jon Otto

Røed, Ole Christian
"Ptychography reconstruction of incomplete datasets"
Supervisor: Breiby, Dag Werner

Samseth, Ingvild
"Solar and lunar tides in the MLT"
Supervisor: Hibbins, Robert Edward

Sandsaunet, Marit Ulset
"Parallel Integration of Aligned Carbon Strings in Polymer Matrix: Dielectrophoretic Preparation, Electrical and Electromechanical Characterisation"
Supervisor: Raaen, Steinar
Geir Helgesen, Matti Knaapila

Skarsvåg, Hans Langva
"Renormalised Intrinsic and Extrinsic Impurity Induced Spin-orbit Scattering in Graphene"
Supervisor: Brataas, Arne

Stige, Kristoffer
"Spin-polarized non-local transport in hybrid structures with magnetic and superconducting correlations"
Supervisor: Linder, Jacob Rune Wüsthoff

Sveinsson, Hrafn Mar
"Constrained Hydrogel Swelling in Biological Sensors. A Finite Element Method Simulaton Approach"
Supervisors: Stokke, Bjørn Torger
Bjørn Helge Skallerud and Victorie Emile Prot

Utne, Amund Fredrik
"High Temperature Stability Tests of Four Ge Containing KK Alloys"
Supervisor: Holmestad, Randi

Vaksdal, Martin
"3D-EPI with parallel imaging acceleration along two Axis Evaluated with Phantom Study and BOLD fMRI"
Supervisor: Lindmo, Tore

Vandbakk, Martin
"Organic Contaminations in Sub-Marine AC and DC High-Voltage Cables"
Supervisors: Støvneng, Jon Andreas
Sverre Hvidsten

Waage, Magnus Heskestad
"Radiative corrections to van der Waals interaction in fluids"
Supervisor: Høye, Johan Skule

Øien, Christian Dalheim
"Simulations of impact using the extended Gurson model"
Supervisor: Støvneng, Jon Andreas
Odd-Sture Hopperstad, Tore Børvik,
Torodd Berstad

Øvland, Ragnhild
"Coherent plane-wave compounding in medical ultrasound imaging. Investigate the quality of 2D B-mode images of static and dynamic objects and images of low velocity blood flow"
Supervisor: Lindmo, Tore
Thor Andreas Tangen

Øyangen, Julia
"Photoprotection of riboflavin containing beverages"
Supervisor: Naqvi, Kalbe Razi

Master of Science in Technology – Nanotechnology

Aursand, Eskil
"Optical properties of truncated and coated spherical nanoparticles on a substrate"
Supervisor: Simonsen, Ingve

Flobak, Åsmund
"Optimization of plasmid transfection using silica-coated cupric oxide nanowires"
Supervisors: Sikorski, Pawel Tadeusz
Astrid Lægreid

Melberg, Brita
"Nanostructured surfaces with patterned wettability"
Supervisor: Sikorski, Pawel Tadeusz

Ribe, Jonas Myren
"Actuation of a Hyperelastic PDMS Membrane Suspended inside a Microfluidic Channel"
Supervisors: Stokke, Bjørn Torger
David Barriet, Øyvind Halaas

Sandvold, Marianne
"Technical Aspects of Ion Milling and Electron Imaging of Epoxy Embedded Samples for FIB/SEM Tomography"
Supervisor: Sikorski, Pawel Tadeusz

Master of Science in Physics

Berzi, Alan
"Relativistic Fermions in Graphene"
Supervisor: Olaussen, Kåre

Fladmark, Bent Even Fossum
"Development and Implementation of new Achromatic Polarimetric Instruments"
Supervisor: Kildemo, Morten

Flovik, Vegard
"The impact of wettability alterations on oil release and transport mechanisms in a 2D porous medium"
Supervisor: Hansen, Alex

Galteland, Peder Notto
"Symmetry Breaking in ordinary and supersymmetric Models of Quantum Field Theory"
Supervisor: Olaussen, Kåre

Lilliestråle, Johan Carl Åke
"Structural properties of Ge doped multicrystalline Silicon wafers and Solar cells"
Supervisors: Walmsley, John
Martin P. Bellmann

Mikkelsen, Alexander
"Experimental Studies of Flow- and Electric Properties of Oil Droplets Including Suspended Clay Particles"
Supervisor: Fossum, Jon Otto

Mørtsell, Eva Anne
"Dispersion hardening during annealing at low Temperatures in four 3xxx Al-Mn-Fe-Si Alloys"
Superviosr: Holmestad, Randi

Orvedal, Ingrid
"Measurement and Modelling of the Water Transport in Water Blocking Tapes for High Voltage Cables"
Superviosrs: Støvneng, Jon Andreas
Torbjørn Ve

Rønning, Snorre Stavik
"Optimizing an Infrared Camera for Observing Atmospheric Gravity Waves from a CubeSat Platform"
Supervisors: Espy, Patrick Joseph
Roger Birkeland, Robert Hibbins

Strümke, Inga
"Field Theory at finite Temperature and Density. Applications to Quark Stars"
Superviosr: Andersen, Jens Oluf

Vestby, Aksel Jan Verne
"Calculation of Terminal Currents in Single Photon Excited Avalanche Photodiodes"
Supervisor: Støvneng, Jon Andreas

Master of Science in Condensed Matter Physics

Gebregiorgis, Ashenafi Weldemariam
"Local Resistivity Measurement on Multicrystalline Silicon"
Supervisor: Gibson, Ursula

Tsegaye, Zenebe Assefa
"Density functional theory studies of electronic and optical properties of ZnS alloyed with Mn and Cr"
Supervisor: Støvneng, Jon Andreas

Master of Science in Science Education

Utsogn, Øystein
"Demonstrations in Optics. Use of new technology in optics by demonstrations"
Supervisor: Kildemo, Morten

PARTICIPATION IN COMMITTEES

EVALUATION COMMITTEES

Andersen, J.O.:
*Administrator of PhD committee for Amna Noreen (Defense December 10th)

Borg, A.:
* Opponent at the PhD defense of Helene Zeuthen, Interdisciplinary Nanoscience Center and Department of Physics and Astronomy (iNANO), Aarhus University, November 2012.
* Administrator for the PhD defense of Åsmund Fløystad Monsen, Department of Physics, NTNU, October 2012.
* External evaluator for the Göran Gustafsson Prize in Physics 2012, The Royal Swedish Academy of Sciences.
* External evaluator for the Wallenberg Fellows 2012, The Royal Swedish Academy of Sciences.
* Member of the evaluation committee on Physics study programs at Swedish universities, Högskoleverket, 2012-2013.

Bungum, B.:
* Opponent for PhD defence of Morten Rask Petersen, Syd-Dansk Universitet

Davies C. de L.;
* Evaluation committee for application on infrastructure to the regional health authorities Helse Sør-Øst
* Evaluation committee for applications to The Norwegian Cancer Society
* Opponent for PhD defence of Maja Mujuc, Univ of Bergen, March 2012
* Evaluation committee/administrator for PhD thesis Jan Rødak March 2012
*Evaluation committee/administrator for PhD thesis Sigrun Almberg August 2012

Gibson, U.:
* Faculty hiring board, American University of Kuwait
* Opponent for Vincent Quemener UiO 12.6.2012
* Administrator for Sedsel Thomassen, NTNU,10.09.2012
* Administrator for Jelena Todorovic, NTNU 3.12.2012

Hansen, A.:
*Evaluation committee for assoc. professorship in physics at the University of Stockholm.
*Evaluation committee for promotion of V. Frette to full professor at Høgskolen i Stord.
*Evaluation committee for professor II position at Department of petroleum technology and applied geophysics, NTNU.
*Opponent at habilitation defense of Daniel Bonamy, Université Pierre et Marie Curie, Paris.
*Administrator for PhD defense of Christer Ersland, Department of Enginering Design and Matreials, NTNU.
*Administrator for PhD defense of Inga Ringdalen Vatne, Department of Engineering Design and Materials, NTNU.
*Administrator for PhD defense of Paul Anton Letnes, Department of Physics, NTNU.

van Helvoort, A.T.J.:
* Opponent for the PhD thesis of Jonas M. Persson, CEN-DTU, Danmark

Hibbins , R.E.:
Administrator for the PhD defense of Rishi Ram Sharma (Physics, NTNU, June 2012)

Holmestad, R.:
*Administrator for PhD defense of Maulid Kivambe (Department of Materials Science and Technology, June 2012)
*Evaluation committee for appointing permanent researcher in electron microscopy, CEN-Denmark Technical University (Nov. 2012)
*Evaluation committee for appointing professor at University in Agder (June 2012)

Kachelriess, M.:
* Panel member of the XMM-Newton Observing Time Allocation Committee.

Kildemo, M.:
* Evaluation committee for appointing associate professor at University of Bergen.

Lindmo, T.:
* Evaluation committee for appointing adjunct professor at University of Bergen.

Olaussen, K.:
* IEEC/CSIC, Campus UAB, Barcelona (Sergei Odintsov)
* Max Planck Institute for Intelligent Systems, Stuttgart (Ania Maciolek)

Reenaas, T. W.:
* Administrator for the PhD thesis of Yu Hi (Department of Materials Science and Engineering), October 2012

Skagerstam, B.-S..:
* Opponent for the PhD thesis of Håkon Brox, Fysisk Institutt, UiO, December 2012.

Stokke, B.T.:
* Evaluation committee for professor position in Nanomedicine, NTNU.

Støvneng, J. A.:
* Administrator for the PhD thesis of Einar Stiansen, Institutt for fysikk, NTNU
* Administrator for the PhD thesis of Iver Sperstad, Institutt for fysikk, NTNU
* Administrator for the PhD thesis of Egil V. Herland, Institutt for fysikk, NTNU
* Opponent for the PhD thesis of Elisa Londero, MC2, Chalmers University of Technology, Sweden

INTERNATIONAL COMMITTEES

Borg, A.:
* Member of "Beredningsgrupp för kondenserade materiens fysik", Swedish Research Council (VR), Sweden.
* Member of the board of The Nanometer Consortium, Lund University, Sweden.
* Member of Administrative Council of SEFI (European Society for Engineering Education)
* Member of the "Program Advisory Committee" (PAC) of MAX-lab.
* Member of the External Advisory Panel, Department of Materials, Imperial College, London, UK.
* Member of the European Science Foundation Materials Science and Engineering Expert Committee (MatSEEC).

Brataas, A.:
* Chairman, Kavli prize in Nanoscience

Bungum, B.:
* Coordinator of Nordic research network in science education, NorSEd, financed by NordForsk.

Espy, P.:
* Member SCOSTEP Climate and Weather of the Sun-Earth System (CAWSES-II) Task Group 2, 2012.
* Member International ALOMAR Science Advisory Committee, 2012.

Fossum, J. O.:
* Project leader of a Nordforsk funded Nordic Researcher Network in Soft Matter Physics (2010-2013) involving ~100 scentists in ~10 groups in the Nordic countries (Denmark, Finland, Norway, Sweden)
* In International Scientific Advisory Board for Center of Physics, Minho University, Braga, Portugal
* In International Scientific Advisory Board for International Center for Condensed Matter Physics (ICCMP), Universidade de Brasilia (UnB), Brasilia, Brazil
*Editor in Cuban Journal of Physics

Gibson, U.:
* 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.
*Chair of the Commission on Computational Physics (C20) of the International Union of Pure and Applied Physics (IUPAP).
*Vice President of the International Union of Pure and Applied Physics (IUPAP).
*Member of the Scientific Advisory Board to the Center of Excellence in Computational systems Research, Helsinki University of Technology.
*Member of Scientific Advisory Board to the Center of Excellence G-Eau-Thermie Profonde, Univ. Strasbourg.
*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.
*Member of the Editorial Board of Journal of Computational Interdisciplinary Sciences.

Holmestad, R.:
* Member of the board of the Nordic microscopy society, SCANDEM.
* Leader of the Nordic network (NordForsk) within TEM – NorTEMnet
* Member of the board of European Microscopy Society

Kachelriess, M.:
* Member of the steering committee of "ISAPP: International School on AstroParticle Physics European Doctorate School".

Lilledahl, M.B.:
* International committees: Management committee member for Cost Action: Chemical imaging by coherent Raman microscopy.

Mathiesen, R. H.
* Member of the Program Advisory Committee of Max-laboratory, Lund University, Sweeden.
* Member of the Scientific Adivisory Comimittee of the European Synchrotron Radiation Facility, Grenoble, France
* Member of the ESRF ID15 5-year beam line review comimittee, European Synchrotron Radiation Facility, Grenoble, France

Stokke, B.T.:
* Editorial Advisory Board – Biopolymers (Wiley).

Sudbø, A.:
*Steering Committee Member, European Science Foundation Network on Nanoscience and Engineering in Superconductivity (NES).
*Member of ESA' Physical Sciences Working Group, European Space Agency
* Member Managing Committee Cost Action MP-1201 Nanoscale Superconductivity: Novel Functionalities through Optimized Confinement of Condensate and Fields
*Advisory Board, Physica C Superconductivity and its applications

NATIONAL COMMITTEES

Borg, A.:
* Member of the Board for the Niels Henrik Abel Prize.

Breiby, D.W.:
* Member of the ColdWear steering committee.

Davies, C. de L.:
* Member of the board of the National Interdisciplinary Research School in Medical Technology

Espy, P.:
* Member, Committee for Co-operation in Space Related Activities between NTNU-National Centre for Space Related Education- Andøya Rocket Range, 2012.

Fossum, J.O:
* Member of the Board of the Norwegian Physical Society
* Chair of the Division for Condensed matter Physics with Atomic Physics in The Norwegian Physical Society

Hansen, A.:
*Member of Board of Trustees, National Museum of Applied Arts, Trondheim.

Holmestad, R.:
* Member of the board of 'Bardalfondet' (Fond for belønning av fremragende studentarbeid innen økologiske aspekt av materialteknologi ved NTNU)

Stokke, B.T.:
* Norwegian national committee for the evaluation of professor competence in physics, member.
* Chairman of the board, NORFAB, National large scale research infrastructure project.

UNIVERSITY AND DEPARTMENTAL COMMITTEES

Borg, A.:
* Member of FUS ("Forvaltningsutvalget for sivilingeniørutdanningen") at NTNU.
* Vice dean on education, Faculty of Natural Sciences and Technology.
* Member of FUL ("Forvaltningsutvalget for Lærerutdanningen") at NTNU.
* Member of Educational Committee of NTNU
* Member, "Studieprogramråd for Lærerutdanningen i Realfag".
* Member of the board at Department of Industrial Economics and Technology Management
* Member of the council for KOMPiS ("Kompetanse i skolen")

Breiby, D.W.:
* Elected member of the departmental board

Bungum, B.:
* Member of the board "Studieprogramråd for Lærerutdanning i Realfag"

Davies, C. de L.:
* Director of NTNU's Strategic Area of Medical Technology.

Espy, P.:
* Head of Section of Applied physics and Didactic Physics.

Gibson, U.:
Program committee for MTFYMA

Holmestad, R.:
* Leader of the TEM Gemini Centre
* Project leader of the large scale infrastructure project NORTEM.

Høye, J.S.:
* Head of Section of Theoretical Physcis.

Lilledahl, M.B.:
* Head of Network for biomedical optics.

Linder, J.:
*Member of 'Formidlingsutvalget', Department of Physics

Lindmo, T.:
* Head of Section of Biophysics and Medical Technology.
* Member, "Studieprogramråd for fysikk og matematikk".
* Chairman, "Studieprogramråd for International MSc Medical Technology".
* Member "Studieprogramråd for PhD i medisinsk teknologi".

Mikkelsen, A.:
* Head of Section of Complex Materials

Olaussen, K.:
* Member of 'Forskningsutvalget', NT-fakultetet
* Chairman 'Formidlingsutvalget', Institutt for fysikk

Reenaas, T.W.:
* Member, "Studieprogramråd for MSc Condensed Matter Physics".
* Substitute for the Elected member of the Departmental Board.

Sikorski, P.:
* Chairman, Study program board, Master in Nanotechnology, NTNU
* Member. NTNU NanoLab leader group

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

Støvneng, J.A.:
* Chairman, "Undervisningsutvalget ved institutt for fysikk".
* Chairman, "Studieprogramråd for MSc Fysikk og matematikk"

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

Wahlstrøm, E.:
* Head of Section of Condensed Matter Physics.
* Member, "Studieprogramråd for nanoteknologi".
* Member. NTNU NanoLab ledergruppen.

ARRANGEMENT COMMITTEES

Fossum J.O.:
*Organizer of Mini-Workshop on Complex Flows and Turbulence, Departamento de Fisica, UFPE Recife, PE, Brazil, December 7, 2012 (Co-organized with Prof. Giovani Vasconcelos, UFPE Recife Brazil)
*Main organizer of International Workshop on Soft Matter Physics and Complex Flows, Svolvær. Lofoten, Norway, May 22 – 25 2012 (Co-organized with Prof. E. Bouchaud. ESPCI-Paris, France)
*In scientific committee of International Conference: New materials in the Age of Convergence, Havana, Cuba, March 12-16, 2012
*Main organizer of International workshop on Complex matter physics: Materials, dynamics and patterns, Havana, Cuba, March 5-8 2012 (Coorganized with Prof. Ernesto Altshuler, Univ. Havana, Cuba)
*Main organizer of International Mini-Workshop on Complex Flows, International Center for Condensed matter Physics (ICCMP), Universidade de Brasilia (UnB), Brasilia, Brazil, February 6-7 2012 (co-organized with Prof. Geraldo Jose da Silva, ICCMP and UnB, Brasilia, Brazil)
* Main organizer of 2nd International Workshop on Complex Physical Phenomena in Materials, Hotel Armacao, Porto de Galinhas PE, Brazil, January 31- February 3 2012 (Co-organized with Prof. Giovani Vasconcelos, UFPE Recife Brazil)

Hansen, A.:
*International Advisory Board Member of Conference on Computational Physics (CCP) 2012, Kobe, Japan.

Holmestad, R:
* Conference chair for 7th International Conference on the Physical Properties and Application of Advanced MATerials (ICPMAT 2012), Trondheim, Norway, June 2012

Kachelriess, M.:
* Member of the Organizing committee of the workshop
* Searching for the sources of Galactic cosmic rays", Paris 2012.
* Member of the International Advisory Board, IPM international school and workshop on Particle Physics (IPP12): Neutrino Physics and Astro-physics", Tehran 2012.

FRIDAY COLLOQUIUM – ”Fredagskollokviet i fysikk”

Convenors: Kåre Olaussen og Jan Myrheim (spring)
Steinar Raaen (autumn)

Programme – spring term

21. januar: Jens Wentzel Andreasen, Solar Energy Program, Risø, DTH:
"Small and wide angle X-ray scattering (SAXS/WAXS) applications in thin film studies".

28. januar: Kimball Milton, University of Oklahoma:
"Casimir Energies and Forces: An Accelerating Subject".

4. februar: Yngve Inntjore Levinsen, CERN:
"Accelerator physics at CERN".

11. februar: Sergey Ostapchenko, Institutt for fysikk, NTNU:
"LHC and its first results".

18. februar: Nils Baas, Institutt for matematiske fag, NTNU:
"Make way for mathematical matter!".

4. mars: Ursula Gibson, Institutt for fysikk, NTNU:
"Magnetic vortices - a new twist for logic gates".

11. mars: Paolo Di Vecchia, NORDITA:
"How a little string can tell us so much".

18. mars: Reidar Stølevik, Institutt for kjemi, NTNU:
"Natural Science and World View".

25. mars, Ingunn Kathrine Wehus, Imperial College and UiO:
"Cosmology — from philosophy to science".

1. april, Yngve Hopstad, Institutt for fysikk, NTNU:
"The Drake equation; Search for intelligent life beyond our planet".

8. april: Jonas Persson, Institutt for fysikk, NTNU:
"What do you care what your students think? What do you think what your students think?"

29. april: Stein Olav Skrøvseth, Telemedisin, Tromsø:
"Applied pattern recognition and statistics in Telemedicine".

6. mai: Asle Sudbø, Institutt for fysikk, NTNU:
!25 years with high-temperature superconductivity (and 100 years with superconductivity)
25 år med høy-temperatur superledning (og 100 år med superledning)!

13. mai: Michiel Postema, Institutt for fysikk og teknologi, UiB:
"Sonoporation".

Programme – autumn term

26. august: Maria Losurdo. University of Bari, Italy.:
"Charge-transfer Processes on the Nanoscale: Role in Plasmonic Hybrid Nanostructures".

9. september: Remi Lazzari, Institut des NanoSciences de Paris, Université Pierre et Marie Curie - CNRS, Paris France:
"Combining GISAXS with in situ techniques to unravel optical and chemical properties of nanoparticles" .

16. september: Katarzyna Sznajd-Weron, Complex Systems and Nonlinear Dynamics Division at the Institute of Theoretical Physics and UNESCO Chair of Interdisciplinary Studies, University of Wroclaw, Poland:
"Social physics or sociophysics?".

23. september: Mark Rudner, Physics Department, Harvard University, USA.:
"Topological Transitions in Driven and Open Quantum Systems" .

30. september: Ernesto Altshuler, Physics Faculty, University of Havana, Cuba:
"Flow induced symmetry breaking of an active suspension through a funnel"

7. oktober: Iwan Rhys Morus. Department of History & Welsh History, Aberystwyth University, Ireland:
"The Theatre of Experiment: Performing the World of Victorian Physics"

14. oktober: Trygve Buanes, Department of Physics and Technology, University of Bergen:
"The Phantom of the OPERA"

21. oktober: Bjørnar Sandnes, Department of Physics, Norwegian University of Science and Technology:
"Displacement structures in multiphase frictional flows" **.**

28. oktober: Henri Van Damme, IFSTTAR and ESPCI ParisTech:
"A physical Approach to the Art of Building".

11. november: Zoltán Néda, Department of Theoretical and Computational Physics, Babeș-Bolyai University, Cluj, Romania:
"The unexpected synchronization".

18. november: Jaques Jupille, Institut des Nanosciences de Paris, Université Pierre et Marie Curie and CNRS:
"Oxide surfaces and interfaces".

25. november: Bodil Holst, Department of Physics and Technology, University of Bergen:
"Matter wave optics with nanostructures"**.**

2. desember: Pietro Ballone, Atomistic Simulation Centre, Queen's University, Belfast:
"Of chains and rings: The equilibrium polymerisation of sulphur".

9. desember: Kevin Smith, Department of Physics, Boston University, USA:
"Intrinsic Electron Quantum Well States in Solids".