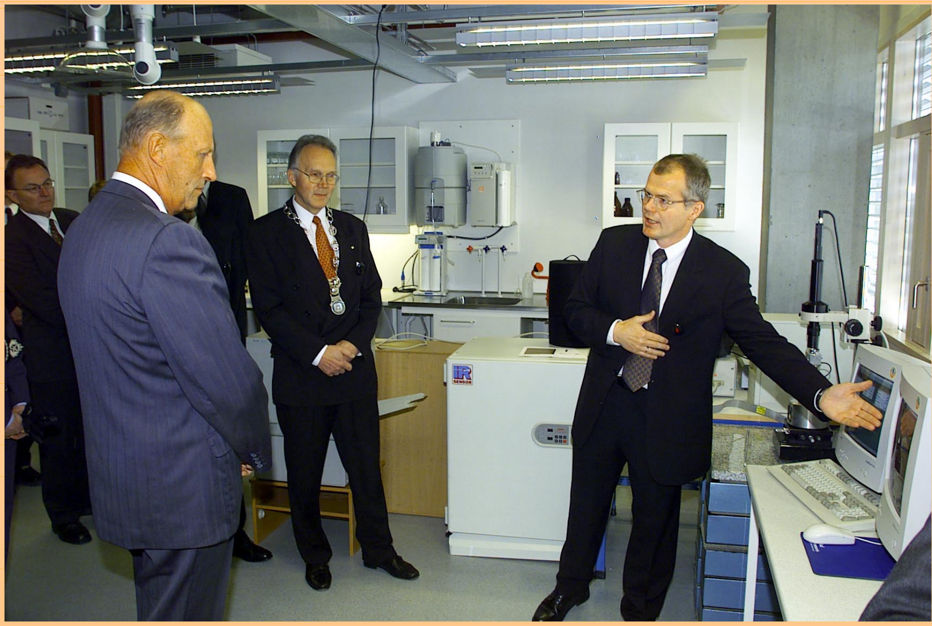
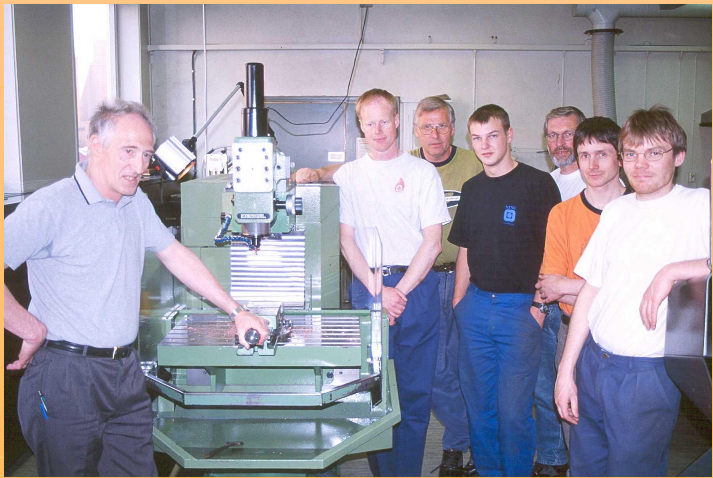
2000

ANNUAL REPORT





NTNU

Department of Physics
Norwegian University of
Science and Technology

DEPARTMENT OF PHYSICS, NTNU

http://www.phys.ntnu.no

CONTENTS

Editors:

Brian, Johs., Lise, and Steinar

Front page:
Upper photo: from the inauguration of the Natural Science Building. HRH King Harald visiting the Section for Biophysics and Medical Technology.
Centre photo: employees of the Departments Mechanical Workshop.
Lower photo: employees of the Departments Electronic Workshop.

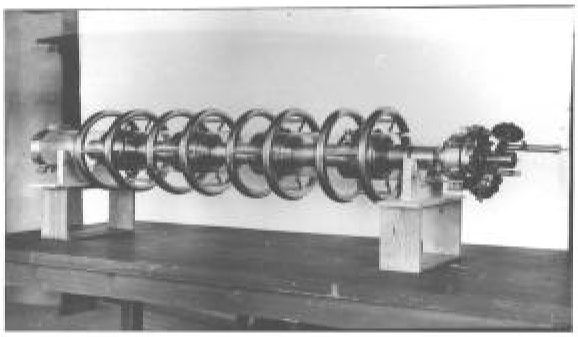
A SHORT HISTORY

The Norwegian University of Science and Technology (NTNU) in Trondheim has roots back to the Norwegian Institute of Technology (NTH) which was inaugurated in 1910 as the first institution in Norway to educate engineers at a scientific level. The task of the first professor of physics, S. Sæland (1874–1940), was to teach mechanics and applied physics, with small opportunities to do scientific research. S. Sæland was the first President of NTH, a member of the Norwegian parliament, and a successful research politician. He managed to strengthen the position of physics at NTH considerably by getting grants for a separate physics building which was completed in 1925. In 1922 a teacher's college (Norges Lærerhøgskole) was also inaugurated in Trondheim, and a lecturer position with teaching duties at this college was established at NTH.

In 1923 the young J. Holtsmark (1894-1975) took over the physics chair. As one of the first propagators of quantum mechanics in Norway he managed to establish a number of very different research activities. He is known for his work on the Stark-effect and the width of spectral lines, and on electron scattering (Holtsmark-Faxén formula). O. Devik, lecturer at the institute 1922 - 1932, was working in geophysics, mainly physics of the ice. Other notable research activities at the institute during the inter-war period were x-ray crystal analysis, technical acoustics, Raman spectroscopy and the construction of a Van de Graaff particle accelerator. This instrument marked the beginning of nuclear physics in Norway. The accelerator tube for the Van de Graaff proton accelerator constructed at the Department of Physics around 1935 is shown below, with the ion source to the right.(Photo: Statsarkivet i Trondheim.)

A number of chemistry students took their diploma thesis in physical chemistry at the physics institute, among these L. Onsager who later received the Nobel Prize for his work in theoretical chemistry and physics. Teaching and research assistants were recruited among chemical and electrical engineers. Some of these assistants managed to achieve important positions in the Norwegian industry. Others went into a scientific career. In 1942 Holtsmark was appointed professor of physics at the University of Oslo. Together with former assistants from Trondheim he came to dominate the academic physics environment in early post-war Norway.

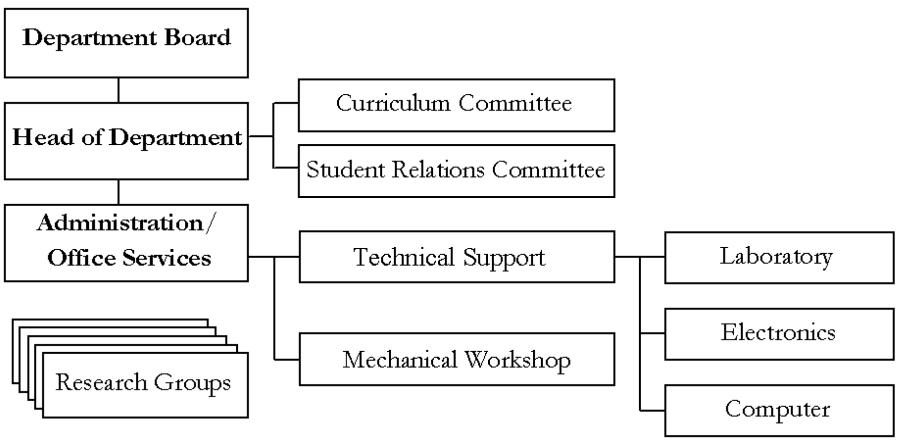
The chair in Trondheim remained vacant until H. Wergeland was appointed in 1946. R. Tangen was appointed in experimental physics in 1948 and S. Westin in technical physics in 1949. S. Westin was a key person in the establishment of the Foundation of Scientific and Industrial Research (SINTEF) at NTH in 1950. The post-war period was characterised by a strong interest in technical physics, and by a steady growth in the research and teaching activity. The enrolment of students increased from 20 in 1961 to about 100 in 1999. The teachers' college also expanded during this period, and a separate physics department was established. Today, the two independent physics departments have merged into a single unity, the Department of Physics, NTNU.

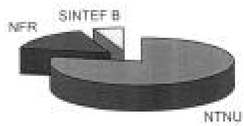


THE DEPARTMENT TODAY

The main tasks of the Department of Physics at NTNU are to provide top quality education of undergraduates and graduate students and to perform research in physics at a high international level. A third important area is to provide the public and non-physics communities with popularized information on topics related to physics. All these tasks are interrelated. The overall goal is to contribute in giving the society a work force of the highest standard.
A major event for the Department has been moving into the new natural science building. This move required a considerable effort on the part of all the departments employees. Most of the year was characterized by the aftermath of these efforts and by initiating the adjustments necessary to fulfill all the requirements for an acceptable tuitional and research environment. Many of these adjustments continued well into 2001.
In 1999 a first version of a strategy plan for the department was written. The strategy process at NTNU requires that the plan should be revised on a yearly basis. An external evaluation committee was appointed in the fall of 1997. The committee consisted of national and international members from the physics community as well as from industry. This resulted in the evaluation report *"Physics at NTNU – in a decade of change"* which was ready at the end of 1998. The ideas and recommendations in this report were subsequently discussed in several internal subcommittees at the department. This resulted in a new strategy for the department. The research activities were divided into four sections: Applied and Didactic Physics, Biophysics and Medical Technology, Condensed Matter Ohysics and Theoretical Physics. The strategy plan for the department gives the following approximate distribution of scientific staff: 30% theoretical physics, 20% experimental biophysics and 50% experimental and applied physics.

Staff	**#**
Professors	*30*
Adjunct Professors	*9*
Associate Professors	*16*
Techn./ Admin. Staff	*30*
Researchers	*6*
Research Fellows	*47*
Student Assistants	*106*





The sectors show the relative contributions from NTNU (42.430 mill. NOK), NFR (The Research Council of Norway; 8.666 mill. NOK) and SINTEF B (2.791 mill. NOK).

EDUCATIONAL PROFILE

Besides educating physisists for industry, business, research and schools, the Department is obligated to provide physics education to students from the technological faculties at NTNU. In addition to lecturing and problem-solving education in information technology and laboratory exercises are given. Especially the last two categories place a high demand on resources.

Education of physicists

In connection with the reorganization that took place during the establishment of a single university in Trondheim a new curriculum for the siv.ing. (graduate engineer) study in physics was initiated. From 1997 new courses were defined as 2.5 vt (credit points), and a full semester of study would then be 10 vt as is the case for other university studies in Norway. At the same time the siv.ing. study was expanded to last 5 years instead of 4.5 years.

A compulsory common course was introduced (5 vt) in the first year of study. For the students of physics and mathematics the curriculum in physics was reduced while that in mathematics was maintained. With this reduced curriculum general topics in physics are given on a basic level.

After 2 years of study the students can choose whether they will continue with physics or with mathematics. Those who choose physics have to take a series of compulsory physics courses during the 5th, 6th and 7th semesters. These courses have a broad basis, and they form a common foundation for continuing studies in one of the various directions that physics can offer. Two of the courses in these semesters, however, are chosen by the student. Biophysics offers courses that are specific for this branch of study.

Semesters 8 and 9 consist of a combination of project work and regular courses. In the latter it is possible to specialize based on a suggested combination of topics and to a certain extent on topics of the students own choice

The Department is in the process of coordinating the siv.ing. curriculum and the standard university curriculum. This process will be further implemented as soon as the whole Department has been united in the new natural sciences building which will take place in 2000. In this way both siv.ing. students and cand.scient. students will be given the full benefit of all physics courses available.

A survey of the curriculum is given on page 22, and a survey of theses delivered in 2000 is shown on page 15.

Doctoral study

Students who have obtained their siv.ing. degree can start to qualify for a dr.ing. degree. Students who have obtained their cand.scient. degree have a corresponding opportunity til qualify for the dr.scient degree. The effective study time to obtain the doctoral degree is stipulated to be 3 years for which financial support is given. This is often extended by periods of 6 or 12 months, depending on external or internal NTNU funding.

A series of courses are given at the post-graduate level. These courses are commonly given each second year. Sometimes they will be given as self studies guided by the supervisor.

The Department of Physics is recognized for the high quality of its post-graduae study. Each year our doctoral students contribute a number of publications to reputed international journals. Our doctoral candidates represent the backbone of the scientific activity at the Department and are thus of invaluable importance.

At present there are relatively few doctoral students in physics. This situation arises after a period with a considerable number of doctoral students. For the Department of Physics it is of importance that this situation does not persist too long. The scarcity of doctoral students is thought to be related to the fact that, at present, it is relatively easy to obtain other, better paid, employment.

Education of engineering students

The Department of Physics carries out an extensive education of students from various technology departments at NTNU. This education consists mainly of introductory physics courses. As a part of several of these courses the students have to do compulsory laboratory excercises. In 1999 around 1400 students took these courses.

The Department of Physics intends to adjust the contents of these courses in accordance with the requirements of the faculties in question. The reorganization of the siv.ing. study from 4.5 to 5 years has resulted in a considerable increase in the need for lecturers for these courses.

Laboratory education

Experimental study of physical phenomena is of crucial importance for all physicists students including those that later specialise in theory. Education in the laboratory contributes both to the understanding of physical phenomena and concepts connected to the laws of nature. Laboratory work is also an important supplement to the lectures. For students that want to specialise in technological or experimental directions, it is of special importance to become familiar with experimental equipment. Besides performing the experiments the laboratory education includes calculation of uncertainties, keeping a laboratory journal, and writing reports. The use of information technology is an important part of this education.

Laboratory teaching has, in the meantime, become very demanding on resources. About 9 - 10 man years from the scientific staff were required for this education in 1999. The major part of the obligatory work load, which forms part of the doctoral students' commitment to the Department, is designated to supervising this education. Furthermore a large part of the technical staff of the Department is used to build and maintain the experimental set-ups

RESEARCH

DIVISION OF THEORETICAL PHYSICS

Protein folding

Physics has made a tremendous impact on medicine and medical technology. What was basic research done because it was fun some decades ago, is now extending people's lives. Just think of the CAT scanner, the laser, ultrasound imaging, or simply the old x-ray tube. There is a revolution going on in molecular biology. Monthly, one finds the complete genome - blueprint - of some simple organism. Soon, we will have the complete genome of ourselves. This knowledge will revolutionize medicine. However, one should note that the growth of knowledge in this field is in width and not in depth. It is the same situation as with computers. Their power is growing exponentially, as a result of ever refinement of the same underlying technology.

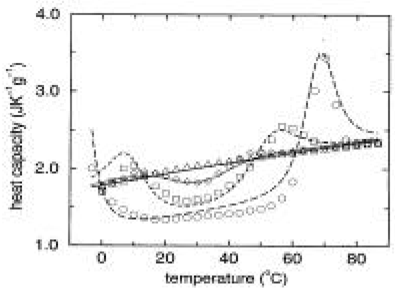
The mission of physicists in molecular biology must be to dig deeper, not wider. For example, once our genome is known, we are at the same stage as egyptology was in the first half of the nineteenth century: Plenty of hieroglyphs had been uncovered, but what did they mean? Only with people such as Thomas Young - who also established the principle of light interference - did they turn into readable literature. The deciphering of the genome is a problem where a physics background and training would be very useful.

Our interest in this field concerns proteins. Proteins are the "machines" that make the cells function. They are chains of amino-acid molecules, which are folded up in well-defined patterns. They do their work by changing between different foldings. Rather than focusing on what makes one protein function differently from other proteins, we are asking what is common between proteins; we are studying the universal features. The ultimate goal is to get to the specificities - but first we must understand the generalities.

Our approach to proteins is a top-down approach. When faced with a protein containing hundreds of amino-acids that interact, the problem of describing its macroscopic structure seems completely overwhelming. This would be a bottom-up approach. The opposite is to acknowledge that there is already a folded structure - never mind how it got to get the shape it has - and from this infer measurable properties such as their thermodynamics. As much is known quantitatively about the thermodynamics of proteins, the top-down description has strong constraints. Once this is in place, we may work our way towards the finer structures of the protein.

So far, we have concentrated our studied on the phenomenon of *cold unfolding* of proteins. Proteins typically exist in two states. They are either folded, i.e. frozen, or unfolded, i.e. molten. If the protein is in the frozen state, it will melt as the temperature is increased. However, many proteins will also melt when the temperature is *lowered*. This phenomenon is cold unfolding. It comes about as a result of interactions between the protein and the surrounding water.

The illustration shows the heat capacity of the protein metmyoglobin as a function of temperature for different acidities (pH-values). The data points are experimental values (Privalov et al., J. Mol. Biol. 190, 487 (1986)), while the curves constitute our theoretical predictions.



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Division of biophysics and medical technology

Biophysics

Light harvesting complexes

Carotenoid pigments are essential components of photosynthetic membranes. They act as accessory pigments, absorbing most efficiently where chlorophyll does not absorb; what is more, they accept triplet excitation from a neighbouring chlorophyll, and thereby prevent the formation of singlet oxygen, which is a toxic reagent. Carotenoids can also quench singlet oxygen but this is a less important route for disarming singlet oxygen. Suppression of singlet oxygen formation is accomplished by extremely rapid triplet-triplet energy transfer. Carotenoid triplets, formed as a result of such transfer, are safe repositories of triplet energy because they are not sufficiently energetic to sensitize singlet oxygen formation. Spin conservation requires the donor and acceptor pigments to be in van der Waals contact and, indeed, the crystal structures of every chlorophyll-carotenoid binding protein determined to date show such contacts. But, crystal structures do not provide interaction energies, only distances. In previous years light-harvesting complexes from photosystem II of plants and a yellow green alga were examined.

This year attention was turned to spinach chloroplasts and chlorosomes from three species, and perturbation of chlorophyll spectra from a nearby carotenoid triplet species was demonstrated in all cases. This is a direct consequence of the electronic interaction between the pigments and adds convincing evidence that specific carotenoid – chlorophyll interactions lie at the heart of photoprotection.

The kinetics of diffusion-controlled reactions in two dimensions differ markedly from the corresponding kinetics in ordinary three-dimensional media; the rate coefficient attains a time-independent value in the latter case, but continues to decrease with time in the former case. In view of the biological importance of two dimensional reactions, their kinetics have been re-examined with a view to validating the existing theoretical expression for the rate coefficient, and for developing a practicable scheme for analysing experimental data on fluorescence quenching in model and biological membranes.

An integrating sphere is often used for recording the absorption spectrum of a turbid sample. If the sample is placed inside the sphere, scattering losses are eliminated, but the recorded spectrum suffers from other distortions. These distortions can be avoided by positioning the sample outside the sphere; but, since some of the scattered light escapes the detector, the recorded spectrum suffers from residual scattering losses. A method has been developed for overcoming these residual losses, and applied to suspensions of cells and sub-cellular organelles.

Medical technology

Imaging of tissue and cells are important for obtaining new knowledge about biological systems and processes. We use optical low coherence tomography (OCT) and methods based on fluorescence such as confocal laser scanning microscopy and multiphoton microscopy, as well as flow cytometry to characterize the distribution of molecules in tissue, and quantify cellular parameters and biological processes. The physics, botany and zoology departments at NTNU have now purchased a new confocal laser scanning- and multi photon microscope.

Optical low coherence tomgraphy

In the present stage of the project we develop instrumentation and methods for optical imaging of tissue based on interferometric reflectometry. The OCT method is in some ways analogous to ultrasound imaging. The coherence length of the light source determines the depth resolution of the measurement, and the probing depth is determined by the optical path length in the reference arm of the interferometer. Three-dimensional data acquisition is obtained by combining the axial interferometric scan with a two-dimensional lateral scan.

The aim of our project is to implement spectroscopic discrimination in the OCT technique, which will enable us to determine concentrations of specific biological agents in the imaged tissue based on differential absorption. This can be used for *in vivo* determination of the oxygen saturation of blood in localized vessels, the transport and diffusion of applied biological agents, or the concentration of specific tissue constituents.

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Transport of macromolecules in tumor tissue

A major problem with conventional cancer therapies such as radiotherapy and chemotherapy is the lack of specificity for the cancer cells. Ionizing radiation and cytotoxic drugs effect both normal and tumor tissue. Tumor specific treatments are thus being developed: Monoclonal antibodies carrying therapeutic agents (radionuclides, toxins) and binding to tumor specific antigens on the surface of tumor cells, gene therapy using DNA vectors carrying therapeutic genes, liposomes carrying cytotoxic agents. However, these tumor-specific therapies are based on rather large molecules with molecular weight more than 150 kDalton and diameters in the order of 10 to 10000nm, whereas conventional chemotherapeutic agents are small molecules below 1nm in diameter. The large molecules have severe problems reaching the tumor cells. The success in reaching and kill the cancer cells depends on 1) the vascular network of the tumor, 2) the ability to cross the capillary wall, and 3) penetrate through the interstitium (i.e. the space between the cells) in concentrations high enough to kill the tumor cells.

The transport across the blood vessel and through the interstitium are governed by convection and diffusion. A major obstacle to accumulation of therapeutic macromolecules in tumor tissue is the high interstitial fluid pressure, impeding convection.

The aims of our research are: 1) to develop a quantitative understanding of the steps involved in the delivery of therapeutic agents, specially the transport in the interstitium. 2) to increase the uptake and penetration of the agents by chemical and physical treatment. The treatments are designed to change the structure and composition of the interstitium in order to increase the diffusion coefficient and hydraulic conductivity, and to reduce the interstitial fluid pressure.

The response of the enzymes hyaluronidase degrading the polysaccharide hyaluronan, and collagenase degrading the collagen network, on the interstitial fluid pressure have been studied. We have shown that both enzymes reduce the interstitial fluid pressure, and probably increase the microvascular-interstitial fluid pressure gradient as the uptake of monoclonal antibody is increased. Using the new confocal laser scanning microscope, multicolor fluorescence microscopy has been done to localize liposomes carrying the fluorescent cytotoxic drug doxorubicin. The endothelial cells of the blood vessels are stained such that the drug can be localized relative to the vessels. Doxorubicin seems to be very heterogeneous distributed throughout the tumor, with a higher uptake around blood vessels in the periphery of the tumor.

DIVISION OF CONDENSED MATTER PHYSICS

Surface nanostructure and spectroscopy

Properties of clean, well-defined surfaces are of fundamental importance in many branches of condensed matter physics and technology. Very often the surface topography turns out to be dominated by monoatomic steps. The statistical distribution function describing the distribution of steps and surface terraces is usually isotropic, but occasionally the step edges tend to be aligned. There is always an energy cost in creating the extra area of a stepped surface, but at high temperatures the lowering in the free energy due to configurational entropy is sufficient to stabilize the structure.

It is well known that steps influence electronic and catalytic properties of surfaces. Step-related effects in optical spectra has been very difficult to study, mostly because the typical step height is much less than both the wavelength of the incoming light beam and the penetration depth in the sample. Using the technique of reflection-anisotropy-spectroscopy, we have recently nevertheless been able to study a clear effect on the optical signal. In reflection-anisotropy spectroscopy one measures the difference between the complex reflection amplitude for light whose polarization is rapidly switched between two orthogonal directions. The switching frequency is typically about 50 kHz. The signal typically originates from the outer 3 - 4 atomic layers and the technique is therefore very sensitive to surface features.

The experiments were performed with oriented and polished Ag(110) crystals in a vacuum chamber. The surfaces of the samples could be studied with low-energy electron diffraction and scanning tunneling microscopy, and were cleaned with cycles of argon ion bombardment and annealing. The experimental results can be summarized as follows: if the surface nanostructure is dominated by aligned steps a strong maximum at 3.8 eV followed by a negative peak at 3.9 eV is observed. When no preferred orientation for the step edges is present the positive low-energy peak is found to be either reduced in strength or completely absent.

Local-field calculations where the screened dipole-dipole interaction coefficients are modified by surface steps are in agreement with these experimental results. Step-induced coupling to surface plasmons is an additional mechanism, which gives a much stronger reduction in the strength of the low-energy peak. The influence of both effects on the spectra increases with decreasing surface correlation length. The plasmon-based mechanism takes place already at lengths of order 10^2 nm, whereas the modified dipole-dipole interaction needs correlation lengths that are almost one magnitude lower to be important.

Self-organisation in deposited layers of polymeric semiconductors

The most outstanding properties of polymeric organic semiconductors are: *(i)* band-gaps in the visible regime that can be tailored, *(ii)* strongly non-linear optical behaviour with ultra-short switching times, *(iii)* processability to any shape, among them thin layers, *(iv)* cheap and flexible materials. Among fields of applications could be mentioned high density data storage, lasers and wide-screen light-emitting diodes.

We have discovered that a high degree of self-assembling takes place during the deposition process in thin layers of various substituted *poly-thiophenes* and also in *poly-pyridine* and in some *poly-anilines*, indicating that the phenomenon is of a general nature.

Three basic ways of deposition have been employed: *(i)* slow deposition from solutions by evaporation; *(ii)* spin coating from solutions; i.e. a drop of solution is applied to a spinning substrate, slinging the material out to a thin layer during rapid removal of the solvent; *(iii)* drop of dilute chloroform solution is applied on top of a water surface; the solvent spreads rapidly, leaving a floating polymer layer.

In some cases the self-assembling could be detected by optical methods, but the effect is most directly observed as a strong structural anisotropy seen by X-ray scattering. The figure illustrates two basic polymer orientations of substituted polythiophenes.

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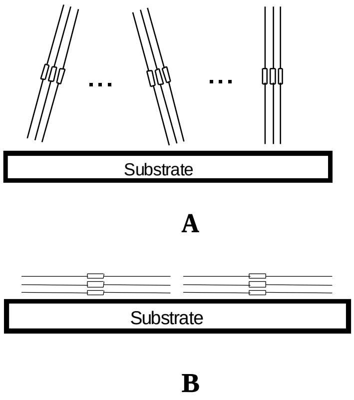

Two types of side chain orientation relative to a film surface or a substrate are shown. Side chains are indicated schematically by lines. Case ***A*** is most common, in our investigations found in all cases except for spin-coated non-stereo-regular *poly-octyl-thiophene*, which takes the orientation type ***B***. Unless particular measures are taken, the material will take all orientation around the substrate normal, and it will correspond to a uniaxial, layered material, with higher conductivity *in plane* than *normal to plane*. The in-plane conductivity is mediated by the conjugated polymer main chains, but also by inter-chain charge transfer (sidewise in ***A***), whereas the *normal-to-plane* conductivity is limited by the alkyl side chains forming *spacers* between the conjugated layers. It is essential to be aware of this intrincic anisotropy when thin-layer devices are made. Thus a layout where the excitation current could run *parallel* rather than *normal to* the substrate could be advantageous.

Poly-dioctyl-phenyl-thiophene is a polythiophene with a different type of side chain substitution (phenyl ring with two octyl groups). It is a strong candidate material for future light-emitting diode devices, showing an extra-ordinarily high luminescence yield. As thin layer it is anisotropic, as revealed by our synchrotron and laboratory x-ray studies.

AWARDS FOR OUTSTANDING RESEARCH

Dennis Gabor Award

Ole Johan Løkberg has been selected for the SPIE 2000 Dennis Gabor Award for his outstanding accomplishments in the development and application of Electronic Speckle Pattern Interferometry (ESPI). Professor of Applied Optics at the Norwegian Institute of Technology's Department of Physics in Trondheim, Løkberg is a recognized pioneer in the area of TV-holography and a world expert in holographic vibration measurement.

An author of more than 95 publications and eight invited book chapters, Løkberg has significantly advanced CCD camera and computer technology as applied to electronic holography.

"Today it is rare to find a single individual so clearly identified with the origins and evolution of a field of science or technology," acknowledged Charles M. Vest, president of the Massachusetts Institute of Technology. "Løkberg carried concepts from optical holographic interferometry into this new field, where the time domain is analogous to the spatial domain in optical holography. Applications ranged from in vivo measurements of the human tympanic membrane to studies of engineering devices and even geological materials," Vest said.

In 1977, Løkberg and his group surprised the world by measuring, with nanometer resolution, the vibrations of the membrane of Løkberg's own ear. In 1994, Løkberg demonstrated the measurement of sound fields by the use of TV-holography.

Løkberg has served as a full professor at the Department of Physics at the Norwegian Institute of Technology since 1988. In prior years, he laid the foundations for his pioneering efforts as a researcher at the University of Minnesota and the Optical Centers at the University of Arizona and University of Alabama Huntsville. He has received numerous awards and fellowships, including being named the first recipient of Norway's national SIMRAD prize in optronics in 1979. He has organized and chaired a number of international meetings.

The Dennis Gabor Award is presented by SPIE -- The International Society for Optical Engineering for outstanding inventive accomplishments in electro?optical systems, especially those that further the development of holographic imaging and metrology applications.

NORSK HYDROS BIRKELANDSPRIS IN PHYSICS

Norsk Hydros Birkelandspris is awarded for outstanding Norwegian research in Physics.

At the Annual meeting of the Norwegian Physics Society the Norsk Hydros Birkelandspris in Physics for 2000 was awarded to **Professor Asle Sudbø** at the Department of Physics, The Norwegian University of Science and Technology.

Professor Asle Sudbø was awarded the prize for his outstanding work in the theory of electronic and magnetic properties of high temperature superconductors.

Professor Sudbø's work is concerned with fundamental properties of superconductors, such as how the properties of superconductors are fundamentally altered when a magnetic field forces its way into it, a research which goes straight to the core of the development of large-scale applications of the so-called high temperature superconductors, presently under intense world-wide investigation. Sudbø and his co-workers at the Norwegian University of Science and Technology in Trondheim have presented a number of novel results on the statistical mechanics of vortex-lines in these systems. Aside from clarifying some deep theoretical issues, this is of great importance for achieving large critical currents in superconductors.

STAFF

Scientific

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Master craftsmen

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THESES

Doctoral study

Aker, Eyvind; *A numerical study of capillary and viscous drainage in porous media.* Supervisor: Professor Alex Hansen.

Brekken, Christian; *Macromolecular transport parameters in tumor tissue and their response to hyaluronidase.* Supervisor: Professor Catharina Davies.

Endresen, Lars Petter; *A theory for the Membrane Potential of Living Cells.* Supervisor: Professor Jan Myrheim.

Fjærestad, John Ove; *Strongly correlated electrons in low dimensions.* Supervisor: Professor Asle Sudbø.

Hansen, Jon-Kåre; *Electronic and Optical Surface Properties of Noble Metals studied by Reflection Anisotropy Spectroscopy* Supervisor: Professor Ola Hunderi / Professor Anne Borg.

Lie, Knut; *Experimental and ab initio Transmission EELS near Edge Fine Structure.* Supervisor: Professor Ragnvald Høier.

Simonsen, Yngve; *New light on rough surfaces: Theories of how they appear and consequences of that.* Supervisor: Professor Alex Hansen.

Thorseth, Trond M.; *Solar ultraviolet irradiance measurements, instrumentation, intercomparisons and interpretations.* Supervisor: Associate Professor Berit Kjeldstad.

Graduate study

Alfredsen, Anne Strand; *Cytotoxic Effects after Intracellular Exposure of HL-60 Cells to the Auger Emitter ^{125}I.* Supervisor: Professor Tore Lindmo.

Aronsen, Sissel; *A New Centrifuge for Intermittent Stimulation of Plants.* Supervisor: Professor Anders Johnsson.

Bjarte-Larsson, Torkel; *Simulations of Model Floating Wave-Power Buoy.* Supervisor: Professor Johannes Falnes.

Botnmark, Hans Kristian; *Genetic Characterization of glnD Mutations which cause increased Osmotolerance in Escherichia Coli.* Supervisor: Professor Tore Lindmo.

Borgos, Sven Even Finborud; *Characterization and Engineering of Genes involved in Regulation and Biosynthesis of Nystatin – an Antifungal Antibiotic – in the Bacterium Streptomyces Noursei.* Supervisor: Professor Bjørn Torger Stokke.

Baarstad, Ivar; *Optical System for Monitoring the Beam Geometry of the ALOMAR Ozon Lidar.* Supervisor: Professor Ole Johan Løkberg

Dahl, Trude Inger; *Dosimetry by Application of an Electronic Multi-Element Radiation Detector for use in Radiation Therapy.* Supervisor: Adjunct Professor Arne Skretting.

Danielsen, Signe; *Calcium changes in Jurkat T-cells during exposure to 50Hz electromagnetic fields.* Supervisor: Professor Anders Johnsson.

Flornes, Olav; *Coupling Fluid Flow and Rock Failure: A New Biot-Cosserat Theory.* Supervisor: Professor Alex Hansen.

Gravbrot, Are; *A finite size scaling study of the critical temperature in the Anisotropic 3D XY-model.* Supervisor: Professor Asle Sudbø.

Graver, Brit Kathrine Frøyen; *Investigation of cube-texture formation during recrystallization of aluminium alloy AA3104.* Supervisor: Professor Ragnvald Høier.

Gudding, Erlend; *Dynamic light scattering Studies of Sodium Fluorohectorite suspensions.* Supervisor: Professor Alex Hansen

Hansen, Yngve Hovel Øverbø; *Self-similar solutions for advection-dominated viscous accretion into black holes.* Supervisor: Professor Erlend Østgaard.

Hatun, Egil Hjalmar; *On the Accuracy of Computing Slope Current Transports from Current Meter Arrays.* Supervisor: Professor Johannes Falnes.

Hauge, Elin; *Surface irregularities after Photorefractive Keratectomy – a study ot the Ablated surface after Myopic and Hyperopic correction in PMMA.* Supervisor: Professor Tore Lindmo.

Hvidsten, Lisbeth; *Dynamic Models for Stiff Systems Applied to an Electrochemical Silicon Furnace.* Supervisor: Professor Ola Hunderi

Høyland, Ole Bjørn; *Vibration Analysis by Moiré-projection.* Supervisor: Professor Ole Johan Løkberg.

Jacobsen, Anders; *Wearable computers – Developments and Possibilities.* Supervisor: Professor Ola Hunderi.

Jensen, Erling Hugo; *Dynamo mechanisms in neutron stars with strong magnetic fields (magnetars).* Supervisor: Professor Erlend Østgaard.

Jenssen, Arne Johannes Kaajik; *Photon production in Electron Positron collisions.* Supervisor: Professor Kjell Mork.

Johansen, Helen; *Measurements of Microvascular Pressure and Interstitial Fluid Pressure Gradients before and after Hyaluronidase Treatment of Tumors, using Micropipette Technique.* Supervisor: Professor Catharina Davies.

Johansen, Yngve; *MAS ^{1}H NMR studies of the bacterium P.acnes exposed to hypertonic treatment and PDT treatment.* Supervisor: Professor Anders Johnsson.

Johannessen, Cecilie Våpenstad; *Dosimetry at the Medical Beamline at the European Synchotron Radiation Facility (ESRF).* Supervisor: Adjunct Professor Arne Skretting

Juul, William; *Knowledge Cooperation – Virtual Networks.* Supervisor: Professor Ola Hunderi.

Knutsen, Steinar; *Development of an image processing system for UNIX. Experimental studies and analysis of plant movements.* Supervisor: Professor Anders Johnsson.

Lieng, Trond; *Implementation of Profibus in the ISOLDE control system.* Supervisor: Professor Kåre Olaussen

Løkken, Øystein; *Modal Analysis of Complex Broadband Hydroacoustic Transducer.* Supervisor: Professor Ole Johan Løkberg.

Løseth, Lars Ole; *Electromagnetic Waves in Layered Media.* Supervisor: Professor Alex Hansen.

Maurstad, Gjertrud; *Optimization and verification of the dose distribution in Tangential Irradiation after Breast-conserving Surgery.* Supervisor: Professor Tore Lindmo.

Nordhøy, Wibeke; *Phase and Amplitude Aberration Correction in Medical Ultrasound Imaging using the signal from Time-Variable, d-correlated Scatterers.* Supervisor: Professor Bjørn Torger Stokke.

Næss, Stine Nalum; *Brownian Dynamics Simulation of Segmented Macromolecules.* Supervisor: Professor Arnljot Elgsæter.

Oddsen, Ingunn Cecilie; *Studies of the HDDR process in TbNiAl.* Supervisor: Professor Randi Holmestad.

Olsøybakk, Kjell Jostein; *Surface Contouring using Structured Light.* Supervisor: Professor Ole Johan Løkberg.

Pettersen, Frans; *Operation of a wind measuring station and quality control of the data. Spectrum analysis and discussion of special time series.* Supervisor: Associate Professor Jørgen Løvseth.

Pettersen, Klas Henning; *The Casimir Effect for a Dielectric Wedge.* Supervisor: Professor Iver Breivik.

Preisig, Stefan Michael; *Radiation from Interacting Binaries.* Supervisor: Professor Erlend Østgaard.

Rekvig, Live; *Use of the Monte Carlo technique in the computation of free energy for the Al-Li alloy system.* Supervisor: Professor Randi Holmestad.

Sand, Åsmund; *The Influence of Magneto-Optic Effects on Surface Plasmon Polaritons.* Supervisor: Professor Ola Hunderi.

Seime, Lars; *Optical studies of the noble metal surfaces Au (110) og Ag (110).* Supervisor: Associate Professor Johannes Bremer.

Simonsen, Beate; *UPS Service Progam.* Supervisor: Associate Professor Tore Høe Løvaas.

Simonsen, Kyrre; *Elastic migration Velocity Analysis with Simulated Annealing.* Supervisor: Professor Alex Hansen.

Sithamparanathan, Jeyanathan; *Development of an image processing system for UNIX. Experimental studies and analysis of plant movements.* Supervisor: Professor Anders Johnsson.

Skudal, Karsten Eeg; *On the calculation of Thouless numbers for Quantum Hall Systems.* Supervisor: Professor Kåre Olaussen.

Stansberg, Christine; *Investigations on the Capacity of Phage Displayed Peptides to Mimic a Neutralizing Antibody Epitope on Friend Murine Leukemia Virus.* Supervisor: Professor Catharina Davies.

Strupstad, André; *Cosmology and Particle Physics.* Supervisor: Porfessor Kjell Mork.

Sundt, Ingunn Helgemo; *Methods to detect ozone, direct and global utraviolet radiation.* Supervisor: Associate Professor Berit Kjeldstad.

Sægrov, Magnhild; *Ultraviolet radiation variability in nature.* Supervisor: Associate Professor Berit Kjeldstad.

Toft, Heidi Kristine; *Klein-Gordon-field coupled to electromagnetism and gravity. Spherically symmetric solutions.* Supervisor: Professor Jan Myrheim.

Undheim, Tor Magne; *Temperature Control of a Drift Tube: Experiments with a Downscaled model.* Supervisor: Associate Professor Tore Høe Løvaas.

Viggen, Kjetil; *Measuring Cardiac Muscle Contraction by Ultrasound Strain Imaging-Feasibility of Angular Correction of Strain Rate.* Supervisor: Professor Catharina Davies.

Wold, Steinar; *Planning, effectuation and evaluation of a curriculim in Physics for future teachers.* Supervisor: Professor Hans Kolbenstvedt.

Øren, Anita; *Use of Brain Cell Cultures to examine the Toxicity of Cerebrospinal Fluid from Patients with Multiple Sclerosis.* Supervisor: Professor Asle Sudbø.

Østbø, Morten; *Oxygen Isotope Characterization of Water Masses and Mixing in the Nordic Seas.* Supervisor: Professor Arnljot Elgsæter.

Østmo, Terje; *Network Model for the Middle Ear.* Supervisor: Associate Professor Magne Kringlebotn.

Årland, Kristine; *Transmission of Gaussian beams into Uniaxial Crystals.* Supervisor: Professor Hans Magne Pedersen.

PUBLICATIONS

Aasmundtveit, K. E.; Samuelsen, E. J.; Guldstein, M.; Steinsland, C.; Flornes, O.; Fagermo, C.; Seeberg, T. M.; Pettersson, L. A. A.; Inganas, O.; Feidenhansl, R.; Ferrer, S. *Structural anisotropy of poly(alkylthiophene) films*. Macromolecules. 33:3120 - 3127 2000.

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Aasmundtveit, K. E.; Samuelsen, E. J.; Hoffmann, K.; Bakken, E.; Carlsen, P.H. J. *Structural studies of polyalkylthiophenes with alternating sidechain positioning*. Synthetic metals. 113: 7 - 18 2000.

Aker, Eyvind; Måløy, Knut Jørgen; Hansen, Alex; Basak, Soumen *Burst dynamics during drainage displacement in porous media: Simulations and experiments.* Europhysics Letters. 55 2000.

Aker, Eyvind; Måløy, Knut Jørgen; Hansen, Alex *Dynamics of stable viscous displacement in porous media.* Physical Review E. 61: 2936 - 2946 2000.

Aker, Eyvind; Måløy, Knut Jørgen; Hansen, Alex Viscous *Stabilization of 2D Drainage Displacements with Trapping.* Physical Review Letters. 84: 4589 - 4590 2000.

Angilella, G. G. N.; Sudbø, Asle; Pucci, Renato *Extended d-wave gap anisotropy in three model theories of high-T_c superconductivity.* International Journal of Modern Physics B. 14: 3306 - 3310 2000.

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Arellano, J. B.; Melø, Thor Bernt; Borrego, C. M.; Garcia-Gil, J.; Naqvi, K. Razi *Nanosecond Laser Photolysis Studies of Chlorosomes and Artificial Aggregates Containing Bacteriochlorophyll e: Evidence for the Proximity of Carotenoids and Bacteriochlorophyll a in Chlorosomes from Chlorobium phaeobacteroides strain CL1401.* Photochemistry and Photobiology. 72: 5, 669 - 675 2000.

Bakk, Audun; Høye, Johan S.; Hansen, Alex; Sneppen, *Kim Pathways in two-state protein folding*. Biophysical Journal. 79: 5, 2722 - 2727 2000.

Brekken, Christian; Hjelstuen, Mari H; Bruland, Øyvind S; Davies, C de Lange *Hyaluronidase-induced periodic modulation of the interstitial fluid pressure increases selective antibody uptake in human osteosarcoma xenografts.* Anticancer Research. 20: 5B, 3513 - 3519 2000.

Brekken, Christian; Bruland, Øyvind S; Davies, C. de L. *Interstitial fluid pressure in human osteosarcoma xenografts: significance of implantation site and the response to intratumoral injection of hyaluronidase.* Anticancer research. 20: 5B, 3503 - 3512 2000.

Bremer, Johannes; Hansen, Jon-Kåre; Stahrenberg, Knut; Worren, Turid *The influence of surface steps on the optical and electronic anisotropy of Ag(110).* Surface Science. 459: 39 - 48 2000.

Donangelo, Raul; Hansen, Alex; Sneppen, Kim; Souza, Sergio R. *Modelling an imperfect market.* Physica A. 283: 469 - 478 2000.

Donangelo, Raul; Hansen, Alex; Sneppen, Kim; Souza, Sergio R. *Physics of Fashion Fluctuations*. Physica A. 287: 539 - 545 2000.

Endresen, Lars Petter; Hall, Kevin; Høye, Johan Skule; Myrheim, Jan *A theory for the membrane potential of living cells.* European Biophysics Journal. 29: 90 - 103 2000.

Endresen, Lars Petter; Skarland, Nils *Limit Cycle Oscillations in Pacemaker Cells.* IEEE Transactions on Biomedical Engineering. 47: 8, 1134 - 1137 2000.

Faaland, Sonia; Einarsrud, Mari-Ann; Høier, Ragnvald Reactions between $La_{1-x}Ca_xMnO_3$ (x=0.3 and 0.6) and CaO-stabilized ZrO_2 powder mixtures studied on a nano-meter scale. Journal of materials science letters. 19: 1379 - 1381 2000.

Falch, Berit H.; Espevik, Terje; Ryan, Liv; Stokke, Bjørn T. *The cytokine stimulating activity of (1->3)-_B-D-glucans is dependent on the triple helix conformation*. Carbohydrate research. 329: 587 - 596 2000.

Frantziskonis, George N.; Hansen, Alex *Wavelet-based Multiscaling in Self-Affine Random Media*. Fractals. 8: 4, 403 - 411 2000.

Hansen, Alex; Jensen, Mogens H.; Sneppen, Kim; Zocchi, Giovanni *Modeling molecular motors as folding-unfolding cycles*. Europhysics Letters. 50: 120 - 124 2000.

Hansen, Alex; Schmittbuhl, Jean; Batrouni, G. George; Oliveira, Fernando A. de *Normal stress distribution of rough surfaces in contact.* Geophysical Research Letters. 27: 22, 3639 2000.

Hansen, Alex; Jensen, Mogens Høgh; Sneppen, Kim; Zocchi, Giovanni Proteins Top-Down: *A Statistical Mechanics Approach*. Physica A. 21 2000.

Hemmer, P.C. *Demixing in isotropic binary mixtures of rodlike macromolecules.* Journal of Statistical Physics. 100: 3 - 11 2000.

Hoffmann, Kenneth J.; Samuelsen, Emil J.; Carlsen, Per H. J.; Graskopf, Arnt L. *Broken pi-conjugated thiophene systems 2.Synthesis and polymerization of di(thien-2-yl) methanol and di(thien-2-yl) methyl octyl ether*. Synthetic Metals. 113: 89 - 92 2000.

Hoffmann, Kenneth J.; Samuelsen, Emil J.; Carlsen, Per H. J.; Knutsen, Linda *Broken pi-conjugated thiophene systems 3.Synthesis and polymerization of 2,2-di(dialkylthien-2-yl) propanes*. Synthetic Metals. 114: 161 - 165 2000.

Hoffmann, Kenneth J.; Samuelsen, Emil J.; Carlsen, Per H. J. *Broken pi-conjugated thiophene systems 4.Synthesis and polymerization of 1,3-di(3,3'-dialkyl-2,2'-bithien-5-yl) propanes*. Synthetic Metals. 114: 167 - 172 2000.

Hoffmann, Kenneth J.; Samuelsen, Emil J.; Carlsen, Per H. J. *Broken pi-conjugated thiophene systems 1.Synthesis and polymerization of 2,2'-di(alkylthienyl) methanes*. Synthetic Metals. 113: 161 - 166 2000.

Hoffmann, Kenneth J.; Samuelsen, Emil J.; Carlsen, Per H. J.; Bakken, Eivind *Synthesis and polymerization of 3,3'-dialkyl-2,2'-bithiophenes.* Synthetic Metals. 113: 39 - 44 2000.

Hove, Joakim; Sudbø, Asle *Anomalous Scaling Dimensions and Stable Charged Fixed Point of Type-II Superconductors.* Physical Review Letters. 84: 3426 - 3429 2000.

Hove, Joakim; Mo, Sjur; Sudbø, Asle *Hausdorff Dimension of Critical Fluctuations in Abelian Gauge Theories.* Physical Review Letters. 85: 2368 - 2371 2000.

Høye, Johan S.; Pini, Davide; Stell, George *SCOZA critical exponents and scaling in three dimensions.* Physica A. 279: 213 - 223 2000.

Høye, Johan S.; Brevik, Iver *The Casimir Problem of spherical Dielectrics: A solution in terms of Quantum Statistical Mechanics.* Journal of Statistical Physics. 100: 223 - 232 2000.

Høye, Johan Skule; Brevik, Iver Håkon *The Casimir Problem of Spherical Dielectrics: A Solution in Terms of Quantum Statistical Mechanics.* Journal of Statistical Physics. 100: 1/2, 223 - 232 2000.

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Kjeldstad, Berit; Johnsen, Bjørn; Koskela, Tapani *Lamps as means to homogenise solar UV irradiance measurements performed with different spectroradiometers.* Journal of Geophysical Research. 105: D4, 4787 - 4795 2000.

Knudsen, Henning Arendt; Hansen, Alex *Diamagnetic susceptibility and current distributions in granular superconductors.* Physical Review B. 11336 - 11339 2000.

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Kringlebotn, Magne *Acoustic impedances at the oval window, and sound pressure transformation of the middle ear in Norwegian cattle*. The Journal of the Acoustical Society of America. 108: 3, 1094 - 1104 2000.

Kringlebotn, Magne *Frequency characteristics of sound transmission in middle ears from Norwegian cattle, and the effect of static pressure differences across the tympanic membrane and the footplate*. The Journal of the Acoustical Society of America. 107: 3, 1442 - 1450 2000.

Kringlebotn, Magne *Rupture Pressures of Membranes in the Ear*. Annals of Otology, Rhinology & Laryngology. 109: 10, 940 - 944 2000.

Leskova, Tamara; Simonsen, Ingve; Maradudin, Alexei *The angular intensity correlation functions c(1) and c(10) for the scattering of light from randomly rough dielectric and metal surfaces*. Communicaciones Opticas. 1: 20 2000.

Lie, Knut; Høier, Ragnvald; Brydson, Rik *Theoretical site and symmetry resolved density of states and experimental EELS near edge spectra of* AlB_2 *and* TiB_2. Physical Review B 61: 3, 1786 - 1793 2000.

Lyman, Charles E.; Lakis, Rollin E.; Stenger, Harvey G.; Tøtdal, Bård; Prestvik, Rune *Analysis of Alloy Nanoparticles*. Microchimica Acta. 301 - 308 2000.

Maradudin, Alexei; Simonsen, Ingve; Leskova, Tamara; Mendez, Eugenio *The design of random surfaces with specified scattering properties: Surfaces that suppress leakage.* Communicaciones Opticas. 1: 28 2000.

Martins, J.; Naqvi, K. Razi; Melø, E. *Kinetics of Two-Dimensional Diffusion-Controlled Reactions: A Monte Carlo Simulation of Hard-Disk Reactants Undergoing a Pearson-Type Random Walk*. The Journal of Physical Chemistry B. 104: 20, 4986 - 4991 2000.

Meerzlyak, M. N.; Naqvi, K. Razi *On recording the true absorption spectrum and the scattering spectrum of a turbid sample: application to cell suspensions of the cyanobacterium Anabaena variabilis*. Journal of Photochemistry and Photobiology B-Biology. 58: 2,3, 123 - 129 2000.

Melø, Thor Bernt; Frigaard, N.-U.; Matsuura, K.; Naqvi, K. Razi *Electronic energy transfer involving carotenoid pigments in chlorosomes of two green bacteria: Chlorobium tepidum and Chloroflexus aurantiacus*. Spectrochimica Acta, Part A. 56: 10, 2001 – 2010 2000.

Midelfart, Anna; Midelfart, Erik; Brodtkorb, Eylert *Visual field defects in patients taking vigabatrin*. Acta Ophthalmologica. 78:: 580 - 584 2000.

Mikkelsen, Arne; Bjørkøy, Astrid; Elgsaeter, Arnljot *Deconvolution can be used in electrooptic studies to correct for non-ideal electric excitation pulses only when the electric dipole moment of the studied molecules is predominantly induced*. Journal of biochemical and biophysical methods. 42: 83 - 96 2000.

Naqvi, K. Razi; Martins, J; Melø, E *Recipes for analyzing diffusion-controlled reactions in two dimensions: time-resolved and steady-state measurements*. Journal of Physical Chemistry B. 104: 50, 12035 - 12038 2000.

Naqvi, K. Razi; Waldenstrøm, S. Revival, *Mirror Revival and Collapse may Occur even in a Harmonic Oscillator Wave Packet*. Physica Scripta. 62: 1, 12 - 16 2000.

Nydal, Reidar *Radiocarbon in the ocean*. Radiocarbon. 42: 2000.

Pedersen, Hans M.; Stamnes, Jakob J. *Radiometric theory of spatial coherence in free-space propagation*. Journal of the Optical Society of America A. 17: 8, 1413 - 1420 2000

Ramstad, Audun; Strisland, Frode; Ramsvik, Trond; Borg, Anne *CO adsorption on the Pt/Rh(100) surface studied by high-resolution photoemission*. Surface Science. 458: 135 - 146 2000.

Ramstad, Audun; Raaen, Steinar; Barrett, Nick *Electronic structure of the La-Pt (111) surface alloy.* Surface Science 448: 179 – 186, 2000.

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Schmittbuhl, Jean; Hansen, Alex; Auradou, Harold; Måløy, Knut Jørgen *Geometry and Dynamics of Invasion Percolation with Correlated Buoyancy*. Physical Review E. 3985 - 3995 2000.

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Sigmond, Reidar Svein *Faraday cage profiles giving self-similar charge drift and conduction in insulator samples*. IEEE Transactions on Dielectrics and Electrical Insulation. 7: 2, 197 - 203 2000.

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Simonsen, Ingve; Lazzari, Remi; Jupille, Jacques; Roux, Stephane *On an optical in situ technique for thin film growth studies*. Communicaciones Opticas. 1: 48 2000.

Simonsen, Ingve; Vandembroucq, Damien; Roux, Stephane *Wave scattering from self-affine surfaces*. Phys. Rev. E. 61: 5914 2000.

Skagerstam, Bo-Sture; Rekdal, Per Kristian *On the Phase Structure of the Micromaser System*. Optics Communications. 184: 185 - 200 2000.

Skagerstam, Bo-Sture; Rekdal, Per Kristian *Quantum Dynamics of Non-Degenerate Parametric Amplification*. Physica Scripta. 61: 296 - 306 2000.

Stokke, Bjørn T.; Draget, Kurt I.; Smidsrød, Olav; Yuguchi, Yoshiaki; Urakawa, Hiroshi; Kajiwara, Kanji *Small-angle x-ray scattering and rheological characterization of alginate gels. 1. Ca-alginate gels*. Macromolecules. 33: 5, 1853 - 1863 2000.

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Thorkildsen, Gunnar; Larsen, Helge B.; Mathiesen, Ragnvald H.; Mo, Frode *Three-beam interference measurements with a six-circle kappa diffractometer*. Journal of Applied Crystallography. 33: 49 - 51 2000.

Thorseth, Trond Morten; Kjeldstad, Berit; Johnsen, Bjørn *Comparison of solar UV measurements performed with spectroradiometer and moderate bandwidth multichannel radiometer for different cloud conditions*. Journal of Geophysical Research. 105: D4, 4809 - 4820 2000.

Thu, Beate; Gåserød, Olav; Paus, Didrik; Mikkelsen, Arne; Skjåk-Bræk, Gudmund; Toffanin, Renato; Vittur, Franco; Rizzo, Roberto *Inhomogeneous alginate gel spheres: An assessment of the polymer gradients by synchrotron radiation-induced X-ray emission, magnetic resonance microimaging, and mathematical modeling*. Biopolymers. 53: 60 – 71 2000.

Velasco, E; Mederos, Luis; Navascues, G.; Hemmer, P.C.; Stell, George *Complex phase behavior induced by repulsive interactions*. Physical Review Letters. Vol. 85: 122 - 126 2000.

Yuguchi, Yoshiaki; Urakawa, Hiroshi; Kajiwara, Kanji; Draget, Kurt I.; Stokke, Bjørn T. *Small-angle X-ray scattering and rheological characterization of alginate gels. 2, Time-resolved studies on ionotropic gels*. Journal of molecular structure. 554: 21 - 34 2000.

CURRICULUM

Siv.ing. study, 1th and 2nd year. ***Student attendance*:**	**1875**
Physics for Civil and Environmental Engineering	138
Laboratory for Physics Students 2	149
Physics for Geology and Petroleum Students	72
Physics for Electronics Students	188
Physics for Chemistry and Metallurgy Students	193
Physics for Computer Students	305
Physics for Machine Technology Students	250
Physics for Marine Students	98
Laboratory for Physics Students 3	124
Laboratory for Physics Students 4	125
Mathematical Physics	134
Physics for Energy and Environmental students	99

Siv.ing. study, 3rd year.	**647**
Physics 2 for Electronics Students	227
Experimental Physics 1	58
Experimental Physics 2	50
Statistical Physics	51
Electromagnetic Theory	48
Atomic and Molecular Physics	59
Optics	50
Quantum Mechanics	36
Physics of Charged Particles	8
Astrophysics	25
Cell Biology 1	35

Siv.ing. study, 4th year.	**286**
Global Transport in Nature	4
Nuclear and Radiation Physics	47
Solid State Physics	33
Energy and Environmental Physics	10
Non-linear Dynamics	11
Physics of Stars	5
Physics and Energy	20
Relativistic Quantum Mechanics	11
Nuclear Physics	11
Quantum Theory of Solids	14
Structure and Properties of Crystals	6
Microstrukture and Mechanical Properties	5
Molecular Biophysics	20
Biophysics (special)	14
Biomedical Technology	17
Physics Project	43
Biophysics Project	15

Dr.ing. study.	**38**
Technical Optics 1	6
Technical Optics 2	2
	4
Non-linear Dynamics	4
Superconductivity	7
Surface Physics	8
	5
Diffraction Theory	1
Polymer Physics 1	1

Cand.mag. study.	**222**
User Course in Physics	27
General Physics I	44
General Physics II	24
Mechanics	19
Electricity and Magnetism	11
Quantum Physics and Statistical Physics	14
Physics Didactics	6
System Dynamics	17
Electronics I	1
Fluid Mechanics	7
Energy and Environmental Physics	7
Biophysics I	10
Quantum Mechanics I	5
Astro Physics I	30

Cand.scient. study.	**75**
Measuring Sensors and Transducers	2
Electronics II	9
Signal Analysis	2
Matematics and Geophysics	3
Quantum Mechanics II	8
Astro Physics II	3
Physics of Stars	8
Cosmology and Extraterrestrial Biology	26
Particle and Nuclear Physics I	8
Particle Physics	6

Dr.scient. study.	**9**
Quantum Field Theory	5
Quantum Flavour and Quantum Chromodynamics	4

Other subjects.	**39**
Electronics	8
Physics in Nature	13
Light, Sight, Colour	2
Physics of the Atmosphere	1
Neutron Stars	14
Space Technology	1