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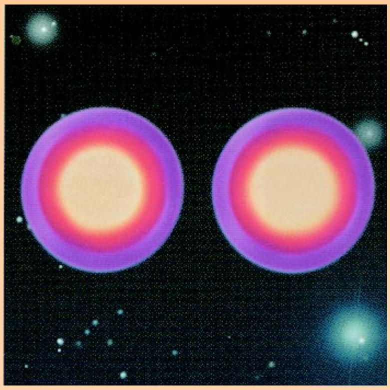

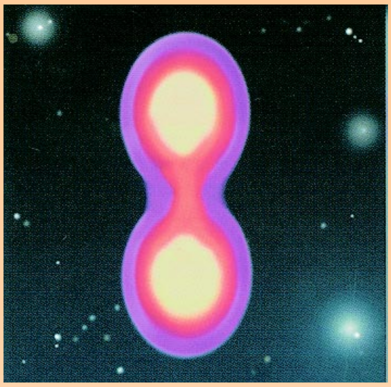

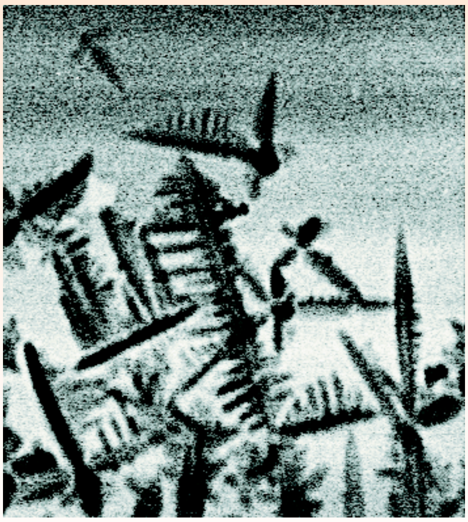

NTNU

Department of Physics
Norwegian University of
Science and Technology

DEPARTMENT OF PHYSICS, NTNU

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Front page, lower part:: dentritic growth in binary alloys. (R.H. Mathiesen, L. Arnberg, F. Mo, T. Weitkamp, A. Snigirev,. *Phys. Rev. Lett.* **83** (1999) 5062.)

Upper part:: collapsing neutron stars. (L.A. Nornes and E. Østgaard. *Astronomi* **29** (1999) 20.)

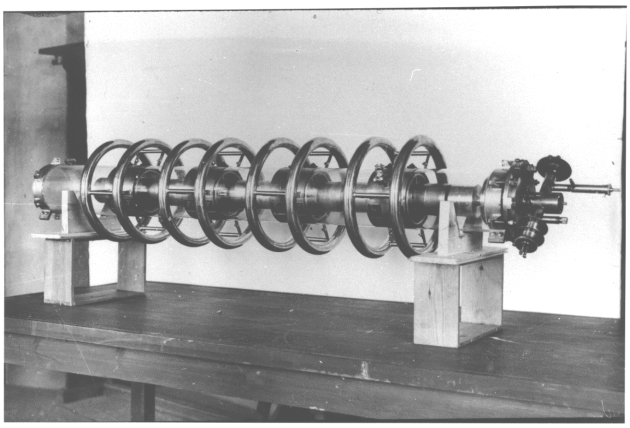
A SHORT HISTORY

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.



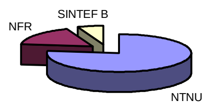
THE DEPARTMENT TODAY

The main tasks of the Department of Physics at NTNU are to provide top quality education of undergraduate 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 standards.

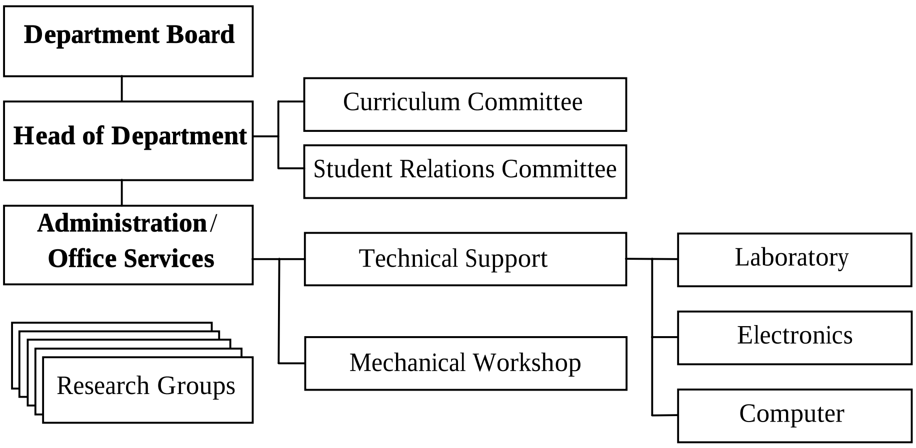
A major event for the Department is moving into the new natural science building. The preparations for the move have been an important issue in 1999. Great expectations are connected with the gathering of the different parts of the physics community in a single building, both as regards research and teaching activities.

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 near 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 in the fall of 1999. A new research group division resulted from this process. The research activities were divided into three main areas, totally encompassing eleven research groups. 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	*29*
Adjunct Professors	*9*
Associate Professors	*16*
Techn./Admin. Staff	*30*
Researchers	*4*
Research of Fellows	*45*
Student Assistants	*72*



The sectors show the relative contributions from NTNU, (40.860 mill. NOK), NFR (The Research Council of Norway; 9.151 mill. NOK) and SINTEF B (3.173 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 1999 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

Astro-particle physics

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In astrophysics one concentrates on problems related to compact stars such as white dwarfs, black holes, neutron stars, quark stars and hybrid stars. Problems under study are: equations of state, quark matter and superfluidity in neutron stars, matter in superstrong magnetic fields, cooling mechanisms, mechanisms for *star quakes*, pion or kaon condensation, and radiation mechanisms in pulsars. In particle physics the focus is on quantum electrodynamics, electro-weak processes, and super symmetry. Quantum dynamics of parametric down-conversion processes and correlation of photons produced in such processes are also studied in the group.

Gamma-ray bursts

Gamma-ray bursts (GRB) have been observed for approximately 30 years, but they still represent an unsolved problem. They represent enormous energies and are probably the strongest explosions which have been observed in the Universe. During the last few years it has been shown that GRBs come from very distant sources outside The Milky Way. An optical afterglow, or longwaved electromagnetic radiation, related to GRBs has been observed, and by identification of the optical sources one can prove that they are extra-galactic. The observed GRBs are varying rapidly, lasting from about 10 msec to approximately 1 hour, producing photons with energies between approximately 10 keV and 1 MeV.

A possible model for GRBs is the *fire ball model*, where the radiation comes from shock waves produced by "mass" shells of photons, neutrinos, electron-positron pairs and baryons, moving at relativistic velocities, colliding with matter outside an exploding star. This explosion then creates a fire ball of gamma rays, neutrinos, etc., and an enormous radiation pressure makes the mass shell and the fire ball expand with relativistic velocities.

A possible source for the explosion may be a supernova-like mechanism, starting with a gravitational collapse of two compact stars in a binary system like the Hulse-Taylor pulsar (PSR 1913+16). It could be a collision between two neutron stars, or a neutron star and a black hole. Such a binary system is not stable, because it emits electromagnetic and gravitational radiation. The two stars will gradually fall towards each other, while rotating around the common centre of gravity, and finally collide or fuse together.

The final unification of the two stars can be a complicated but very fast process, where enormous tidal forces will distort the stars strongly, and the least massive neutron star will be torn apart and become an accretion disk around the most massive star. If we have two neutron stars, the most massive star will become larger than the critical upper mass limit for neutron stars, and a black hole is created. The rest of the accretion disk will fall into the black hole within seconds. And this violent final gravitational collapse of the binary system will produce strong gravitational radiation and an explosive out-burst of gamma-rays and neutrinos, electron-positron pairs and baryons. Theoretically, this could generate energies of the order of 10^{46} J, which is sufficient to explain a GRB.

Condensed matter theory

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The members of the group work on a wide range of problems, some of which can be treated within classical physics, and others where quantum mechanical effects are essential. A major part of the activity is within the field of statistical physics.

Classical statistical mechanics

A fundamental problem, of long tradition, in classical statistical mechanics is the computation of equations of state and phase transitions, from known interactions between particles, in simple fluids, in colloids, which consist of relatively large particles, and in spin systems or lattice gases. Correlation functions are studied and used to obtain the equation of state, and in particular, a self-consistency scheme that yields accurate results has been developed.

Other problems under investigation are self organization in the development of cracks in brittle materials, where the surfaces of fractures have fractal properties. Fractals are curves and surfaces of non-integer dimensions, which are self-similar when viewed on all different scales, thus having no intrinsic scale. Granular media, like sand, powder and disordered media, may have a fractal structure within a certain range of scales. In particular, transport processes in disordered media are studied, such as the streaming of liquid and gas together in porous rocks, and electric currents in a crystal with impurities. Synthetic clays are also studied, in close collaboration with experimentalists.

Molecular biology is now undergoing a revolution. The amount of data that is becoming available is staggering. In biological physics, attempts to systematize and interpret the biological data in terms of physical mechanisms through studying proteins are made. Of particular interest for the moment is their thermodynamical properties, in particular the so-called cold denaturation transition, where the protein melts as the temperature is lowered.

Our activity in biophysics concerns the modelling of spontaneously active heart cells, where the basic mechanism is ion transport through the cell membrane by a number of different proteins.

Critical states and universality are key words in many of the examples mentioned above. Universality means that the behaviour of one system close to the critical state is quantitatively similar to the behaviour of many other systems having seemingly little or nothing in common.

Quantum mechanical problems

An example of quantum mechanical effects being studied is the Casimir effect. This produces, for example, a measurable force between parallel plates at short distances, and the usual statement is that the force arises because the energy density of the vacuum fluctuations of the electromagnetic field varies with the separation of the plates. The same picture gives a quantitative description of the forces between molecules known as van der Waals forces. An alternative interpretation of the van der Waals forces is in terms of the dispersion forces due to thermal fluctuations of dipolar moments of polarizable particles, interacting via the electromagnetic field. It is an interesting new result that the two different ways of describing the same phenomenon are shown to give identical result.

Other examples are semiconductor physics, both in three, two, one and zero dimensions. Special phenomena occur when electrons are constrained to move on a two dimensional surface, along a one dimensional string, or are captured in a point-like trap.

Various aspects of the quantum Hall effect are studied. This effect may arise when electrons are captured on a surface, at temperatures below one kelvin and in a strong transverse magnetic field. Then the observed Hall conductance is quantized in either integer multiples or rational fractions of the ratio e^2/h, where -e is the electron charge and h is Planck's constant. Disorder is generally believed to play an important role.

The fractional quantum Hall effect was highlighted by the award of the 1998 Nobel prize in physics. It is understood as a manifestation of strong correlations between the electrons, induced by their mutual Coulomb repulsion. The fundamental excitations of the system are believed to be quasiparticles of both fractional charge (charges are fractions of the elementary charge e) and fractional statistics (an interchange of quasiparticle positions may give a complex phase factor in the wave function that is neither +1, as for bosons, nor -1, as for fermions). Particles with fractional statistics in two dimensions are known as anyons. In a model introduced by Jain, the integer and fractional quantum Hall effects are treated more on an equal footing than is the case in the original theory of Laughlin, the electrons are seen as a special kind of anyons, called composite fermions.

Superconductivity

High-temperature superconductors confront us with a host of deep problems in physics, characteristic of a situation where perturbation theory or resummations of perturbation series do not work. This is a truly remarkable situation, rarely encountered. It is enough to recall the spectacular success of Landau's Fermi-liquid framework which for more than 50 years has formed the cornerstone of our understanding of metals: the correct paradigm for most metals is the free-electron gas! This holds true even for extremely strongly correlated fermion systems. In heavy-fermion compounds correlation effects render the effective electron mass up to 1000 times that of the bare electron mass. Nonetheless, the low-energy excitations of the system are electron-like quasiparticles. Well-known examples of non-Fermi liquids are one-dimensional electron systems and the quantum Hall systems, and the ground states and excitation spectra are essentially understood. The high-T_c superconducting copper oxides (HTSC) are certainly non-Fermi liquids, but the character of their low-energy excitations remains elusive. They are antiferromagnetic insulators at half-filled bands, where even the most sophisticated band theory calculations predict a metallic state. The insulating state is referred to as a Mott-Hubbard insulator. The doped Mott-Hubbard insulators (DMHI) form a new state of matter which has yet to be understood.

It has proved fruitful to write down an effective field-theory of the superconducting state of DMHI, based on general symmetry principles. It turns out to be represented by a complex scalar matter field coupled to an abelian massless gauge-field. In three dimensions, and three dimensions only, research carried out over the last four years at NTNU and the Johns Hopkins University, USA, has explicitly demonstrated that the topological defects of this theory form closed vortex-loops of quantized vorticity. A specific feature of three dimensions is that the system of such interacting vortex-loops may itself be written in terms of a field theory consisting of a complex matter field coupled to some gauge-field which may or may not be massive, depending on the charge of the original condensate. This theory constitutes a dual description of the original system.

In three dimensions, a unique situation arises: the dual of a charged superconductor is isomorphic to a neutral superfluid, and vice versa. This allows us to establish a connection between anomalous scaling exponents of the charged field theory, and geometric exponents characterising the geometric properties of the critical fluctuations of the neutral theory, namely topological excitations in the form of a vortex-tangle. At the critical point, the line tension of the vortex-loops vanishes and the system suffers a vortex-loop blowout, which is the 3D analog of the well-known Kosterlitz-Thouless transition in 2D.

Vortex-loops are particularly prominent in DMHI, because they originate in transverse phase-fluctuations of the original complex matter field. The stiffness of this phase is essentially the superfluid stiffness which is small in DMHI, since the DMHI are extremely poor conductors with low charge-carrier density. In good metals with large charge carrier density, the phase-stiffness is large, suppressing vortex loops except for extremely close to T_c. This is why the celebrated mean field description of Bardeen, Cooper and Schrieffer works so well in describing the superconductor/metal transition in systems such as Pb, Sn, Hg, and Al, while it fails in the HTSC systems.

Surface physics

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J. Bremer
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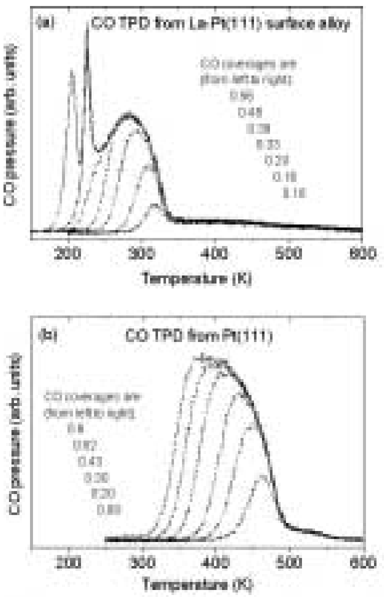
Surface science is an interdisiplinary activity with links to both physics, chemistry and electronics. The research interests of the group members are studies of clean surfaces, with and without adsorbates, and their electronic, structural, optical, and catalytical properties. The main experimental techniques are photoelectron spectroscopy, low-energy electrondiffraction, temperature programmed desorption, ellipsometry, reflection-anisotropy spectroscopy, infrared spectroscopy, and scanning tunneling microscopy.

Studies of La-Pt surface alloys

The presence of a low-workfunction element at the platinum (111) surface has the effect of lowering the electrostatic potential. The catalytic activity is thereby altered. An overall description of a given catalytic reaction is difficult because a substantial number of other properties of the catalyst may also have been changed by the adsorbate; e.g. adsorption sites and surface mobility of adsorbed species, structure and electronic structure of the catalyst, the number of active sites, etc.

Electronic promoters play an important role in heterogeneous catalysis. Platinum doped by low- workfunction elements like rare earth metals may constitute an important system for studying catalytic promotion. Frequently, simple model systems may give useful insight into real catalytic processes as well as fundamentals of adsorption and desorption of various gas molecules. Rare earth elements are well suited as dopants in catalysts since they have low surface free energies. They therefore have a tendency to be located at or near the surface in an actual catalytic system, and will thus directly influence adsorption and desorption of various gas molecules.

La overlayers on a Pt(111) crystal have been studied by photoelectron and thermal desorption spectroscopies. The motivation for the study was to modify electronic and structural properties of the Pt(111) surface to change its reactivity. The formation of an ordered surface alloy as well as adsorption of CO and O_2 on the surface alloy has been investigated. Thermal desorption spectra (see figure) show that the La-Pt alloy is more *inert* to adsorption of CO than the pure Pt(111) surface at ambient temperatures. The electronic structure is dramatically changed upon formation of the surface alloy. The workfunction of the La-Pt alloy is measured to be about 1 eV smaller than that of pure Pt(111). An analysis of the thermal desorption spectra show that the desorption energy is considerably lower in the case of the surface alloy. The dependence of desorption parameters with CO coverage shows that the desorption depends strongly on lateral interactions in the adsorbed layer. Further experiments on related surface alloy systems are planned



Temperature programmed desorption spectra of CO from La-Pt(111) surface alloy (top panel) and from pure Pt(111) (bottom panel). The lower desorption temperatures in the top panel indicate weaker binding of the CO molecules to the substrate.

Material physics

Research on materials is of fundamental importance in science and technology. At the Department of Physics research has in the past been carried out on the structure, thermodynamics and flux line dynamics in a number of high-T_c compounds. Presently the elastic properties of the flux line system is being investigated by ultrasound. The introduction of nanoparticles like carbon nanotubes, MgO etc. into the superconducting matrix is pursued to achieve better pinning and higher critical current.

In traditional materials science the experimental activity is built up around a 300 kV electron microscope. The research focuses mainly on quantitative electron diffraction, high resolution microscopy and spectroscopy methods, atomistic modelling, studies of Al and Mg alloys, TiAl intermetallics and high-performance ceramics.

Research on organic semi-conductors/conducting polymers like polythiophenes is also carried out. Diffraction and spectroscopic methods are used, and the emphasis is on low-dimensionality properties. Orientation effects of ultra-thin layers (10-200 nanometer) on solid and liquid substrates are studied.

In x-ray crystallography the major activity is related to the physical estimation of triplet phases from three-beam interference experiments, and the use of synchrotron radiation in structural analysis. The work described below, which is based on measurements at the European Synchrotron Radiation Facility in Grenoble, France, has brought forward new informtion about dendritic growth, and has drawn considerable attention. .

Dendritic growth in binary alloys

A solid-liquid interface propagating under non-equilibrium conditions will often exhibit macroscopic structures that resemble trees or snowflakes. Under favourable conditions, such growing fronts, called dendrites, can be conserved in solidified alloys. Dendritic interfaces form when one of the alloying elements nucleates into growing crystals with ability both to dissipate and receive heat from the melt. Away from equilibrium, the phase front does not form according to energy minimization principles. It is instead anisotropic with preferred growth along crystallographic directions that correspond to a maximum expansion rate for the solid.

Among equivalent directions, growth is promoted for the one falling most parallel to the global gradient as this over time will be most exposed to excess liquid. As the interface increases in size, a constitutional problem for further growth arises as liquid composition near the interface shifts towards the minor alloying element. To continue the growth process, the interface adopts a shape that allows the excess atoms to diffuse back into the liquid. The chemical diffusion length is small compared with its thermal counterpart(s). Accordingly, chemical gradients will have the largest impact on morphology and interface propagation. Nearby interfacial segments may interact through diffusion, and gradient dynamics may result in liquid convection. Non-local analytical solutions to the diffusion fields do not exist, even in the simplest case of a one-way single diffusion process. The interface itself is a free value boundary at which both kinetic and thermodynamic conditions must be specified. A non-linear integral equation results for which numerical approaches have produced

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models for dendritic growth, yet none of these involve all physical parameters believed to be of importance.

Development of consistent growth models have been limited by experimental difficulties. Until now, the methods have been limited to the use of phase contrast microscopy and a few transparent organic systems which solidify with morphologies analogue to metals. Although such studies have provided important data for simulations, discrepant properties between organic systems and metals, such as viscosity or heat conductivity, limit their general applicability. Furthermore, the systems do not form alloys with optically opaque elements allowing studies of local segregation. Recently, a new method for in situ studies of dendritic growth in metals using high-resolution, time-resolved X-ray imaging techniques have been developed. The first experiments, performed at beamline ID22, ESRF, Grenoble, on PbSn alloys, showed that the method is well-suited for simultaneous dynamic studies of front morphologies and phase-specific segregation phenomena.

Biophysics

The research in molecular biophysics includes studies of macromolecules and nano particles, and encompasses both experimental and theoretical work. The main experimental methods are electron and atomic force microscopy, rheology and various spectroscopic methods. Extensive use is made of classical statistical physics and numerical simulations in connection with modeling and analysis of experimental data.

Biopolymers

Biopolymers constitute one of the main components of all organisms and include DNA, RNA, proteins and polysaccharides. The functional roles span from being information carriers (DNA and RNA), highly specific catalysts (proteins and RNA) to being the main components of an organism's force generators (e.g. muscles) and load carrying structures (e.g. cellulose in plants and chitosan in shrimp shells). A detailed understanding of life is therefore impossible without a molecular understanding of the functional mechanisms of biopolymers. In addition, biopolymers are of great applied value in medicine, biotechnology, and the food and paper industry.

The functional mechanisms of many biopolymers depend on how fast and to what extent the molecular structure is changed as result of thermal fluctuations or as result of the interactions with other molecules. Studies of these phenomena, polymer dynamics, have until recently in part been hampered by the lack of a firm theoretical foundation for more realistic polymer models, which in turn has resulted in low interest for attempting to obtain further improvements of the experimental methods.

At the Department of Physics a major effort has been made over the last few years to try to break the deadlock described above. Employing kinetic theory we have now succeeded in establishing the theoretical foundation for Brownian dynamics simulations of polymers consisting of stiff segments with arbitrary geometry and flexible or rigid links. This represents a major step forward, but it still remains to establish the most efficient approach to achieving a detailed calculation of the mobility tensor of such polymer models. In parallel with this theoretical work we have been designing and building a new state-of-the-art instrument for electro-optic measurements of the rotation and flexing dynamics of biopolymers. This close coupling between theoretical simulations and advanced experiments in sum make us well poised for making important progress in obtaining an improved quantitative understanding of biopolymer dynamics.

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A. Mikkelsen
B. S.. Stokke

Biosystems

In system biophysics the focus is on the properties of cells and organisms. Most of the experimental activity in photosynthetic research has been concerned with the interaction between chlorophyll and carotenoids in photosynthetic antennae. The effieciency of singlet energy transfer has been measured by means of fluorescence excitation spectroscopy; that of triplet energy transfer by means of time-resolved, multi-channel absorption spectroscopy.

A. Johnsson
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Light destructions of cells - NMR-investigations

Light is increasingly used to destruct cells in a controlled manner. The method is based on the idea that certain molecules, so-called *sensitizers,* can be taken up by the cells and light can be used to excite the molecules. The excited sensitizer can then start specific reactions in the cells that lead to cell destruction. The method is used in cancer treatment where porphyrin molecules are produced in the cancer cells and is excited with red light through the skin of the patient.

Cellular reactions that take place after such porphyrin excitation are studied. The porphyrins are created in either cancer cells of so-called Jurkat T-cells (human leukemic cells) or in bacteria, *Propionibacterium acnes*. This type of bacterium, in fact, produces much porphyrins by themselves. The cellular destruction is probably occurring by reactive oxygen destruction of cellular membranes. The studies are based on light spectroscopic techniques, but recently NMR techniques have been taken in use. Socalled MAS NMR techniques reveal an abundance of information from the cell constituents. The technique is based on a method to spin the cell suspension in the NMR magnet and provides sharp molecular spectra. By following the spectral changes in proton spectra as light is destructing the cells the molecular changes that occur can be identified.

(Figurtekst) 1H MAS NMR spectrum of normal Jurkat cells (upper spectrum) and the difference between spectra of red light treated cells and normal cells (lower spectrum). The treatment induces changes in several metabolic processes. The difference spectrum shows an increase in signals arising from different parts of lipids, and a decrease in choline-containing molecules.

Health effects and mobile phone exposure

Some people complain about headaches and other symptoms in connection with the use of mobile phones. In a Swedish-Norwegian epidemiological investigation we found that groups using the mobile phone very frequently had the highest risk of having various symptoms. Such a statistical relation may be due to various factors associated with mobile phone use. Among suggested factors, the radio frequency electromagnetic fields around the mobile phone antenna are often discussed, also in mass media. However, so far scientific research has not been able to confirm or deny a potential health effect of the radio frequency exposure. The current drawn from the battery of the mobile phone generates low frequency magnetic fields, and also cause the mobile phone to be somewhat heated. These factors should be considered when trying to explain the observed relations between mobile phone use and occurrence of reported symptoms.

In a follow-up project from the epidemiological study, both low frequency magnetic fields close to mobile phones, and the amount of radio frequency energy that is deposited in the head by various mobile phones are measured. It is, for instance, of interest to know whether a significant part of the energy is absorbed in sensitive nervous tissue or not. To see whether elevated temperatures may explain unpleasant sensations skin and mobile phone temperatures have been measured by the use of infrared camera.

The front/back??? page pictures show a person before and after half an hour mobile phone use. The increased temperature is seen as a change in colour of the ear region; see temperature scale at the right.

Energy and environment

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Solar radiation, and in particular the UV-component is monitored on a regular basis. A new station has been established on Gråkallen, a mountain of 556 m elevation 10 km west of the university campus. This station will give the opportunity to study the effect of snow cover on the total radiation level.

Research on the conversion of wind and ocean wave energy is carried out. The extreme values of wind gusts and the structure of wind turbulence are of critical importance for the design of wind turbines and other wind exposed structures. The wind research station near Titran, on the western tip of the island of Frøya, has four masts of heights up to 100 m, and is well equipped with sensors to study turbulence and correlation in the wind field. In 1997 the Engineering Committee on Oceanic Resources (ECOR), an international organisation, set up the ECOR Working Group on Wave Energy Conversion. Professor Falnes is a member of this group. Members of the group have produced several draft versions of a wave-energy review, and a final version is currently under preparation.

In hearing research the main effort is in ear mechanics and modelling. The aim is a best possible understanding and description of the acousto-mechanical system of the ear. Some result examples from an extensive measuring program are: rupture pressures of membranes in the ear, transfer function from sound pressure at the eardrum to volume displacement in the inner ear windows, and the influence of static pressure differences across the tympanic membrane and the footplate. Measuring objects have been ears from cattle. The middle and inner parts of these ears have about the same size as for humans.

Laser light scattering from fluid-fluid interfaces

The interface between two fluids at rest is not perfectly planar at microscopic level. Random molecular motions excite ripples at the interface. Such ripples typically have amplitudes and wavelengths in the nanometer and micrometer range, respectively. Their propagation is, by contrast to larger wavelength gravity waves, governed by interfacial tension. When a laser beam illuminates such ripples at the interface between two fluid phases of different optical density, a small but detectable amount of light is scattered out of the laser beam. Analysis of temporal intensity fluctuations of the scattered light provides information about the fluid properties governing the ripple propagation – mainly the interfacial tension and fluid viscosities.

As a non-contact and non-perturbative technique, interface light scattering is particularly well suited for measurement of interfacial tension characteristics of near critical fluid systems. It is also very well suited for measurement at elevated pressure and temperature. In co-operation with SINTEF Petroleum Research, this technique has during the last decade been employed for measurement on hydrocarbon gas/condensate systems at reservoir conditions. Knowledge of interfacial tension in hydrocarbon systems at reservoir conditions is important for optimisation of oil recovery. Projects have been conducted for both Norwegian and international oil companies, involving both natural and synthetic gas/condensates.

In 1999 interfacial light scattering was employed for the study of a synthetic gas/condensate to investigate further an anomaly in the interfacial tension previously observed in a similar synthetic system. An explanation for the anomalous pressure dependence has not yet been found.

Radiocarbon in the ocean

A review paper on the distribution of radiocarbon (C-14) from nuclear tests in the atmosphere has been written. The paper covers a period of about 40 years (1955-1995). Radiocarbon is mostly known as an isotope used for the dating of organic material in archaeology and geology. Before the atomic bomb, there was equilibrium between production of the C-14 isotope by collision of cosmic ray neutrons with nitrogen nuclei in the atmosphere and decay. The ratio of C-14 decreased somewhat from the onset of the industrial revolution due to the burning of fossil carbon, and was drastically increased by additional C-14 when the testing of nuclear bombs started. These tests came partly to an end in August 1963 as a result of the The Moscow Treaty. At this time the amount of C-14 in the northern atmosphere was nearly doubled. This excess has later on gradually been transferred to various reservoirs in nature, especially the ocean. Radiocarbon is combined to a CO_2 molecule in the atmosphere and can serve as an efficient radioactive tracer for the diffusion of atmospheric CO_2 into other reservoirs. A main question in the climate research is how fast the ocean is able to absorb the excess of CO_2 from fossil fuel. Bomb C-14 has during later years proved to be an efficient tool to study of the distribution of CO_2 from fossil fuel.

The review paper summarises the research done by several nations to study the penetration of C-14 into the ocean. The first bomb carbon in the sea surface was observed in 1955 in the Pacific Ocean. Later on the ocean surface has been widely mapped. Our Radiological Dating Laboratory had an agreement with the shipping companies Wilh. Wilhelmsen and Fred Olsen to collect surface samples for 30 years in the Pacific, Atlantic and Indian oceans, which were subsequently analysed. The penetration of C-14 into the deep ocean has been further studied by measurements at various depths in large international programs. With a large number of measurements in all oceans at various depths it will be possible to model the ocean uptake of CO_2.

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THESES

Doctoral study

Berit Margrethe Hasle Falch, *Macromulecular triplex structures of the fungal (1→3)-β-D-glucan scleroglucan, and immunostimulating effects in vitro.* Supervisor: Professor Bjørn Torger Stokke.

Gudrun Kristine Høye: *Oscillations in Neutron Stars.* Supervisor: Professor Erlend Østgaard.

Inger Lindseth, *Optical total reflectance, near-surface microstructure, and topography of rolled aluminium materials.* Supervisor: Professor Ragnvald Høier.

Anh Kiet Nguyen, *Phase transitions in extreme type-II superconductors: Topological defects, and dual description of the vortex system.* Supervisor: Professor Asle Sudbø.

Audun Ramstad: *Surface science studies of model bimetallic catalyst systems.* Supervisor: Professor Steinar Raaen.

Yan Tang, *Quantification of low Mg and Si concentrations and Mg diffusion in Al* Supervisor: Professor Ragnvald Høier.

Knut Eilif Aasmundtveit: *Structure of various substituted polythiophenes, studied in bulk and thin films.* Supervisor: Professor Emil J. Samuelsen.

Graduate study

Kjetil Areklett: *Laser Induced Electrical Discharges in Air with DC Stressed Rod to Plane Gap.* Supervisor: Professor Reidar S. Sigmond.

Audun Bakk: *Dynamic renormalization group analysis of the Kardar-Parisi-Zhang equation with spatial noise and its connection to the non-directed polymer model.* Supervisor: Professor Alex Hansen.

Jon Kristian Behring, *A Study of Attenuation Correction Applied in Positron Emission Tomography (PET) on a Dual Detector Gamma Camera System Operated in Coincidence Mode.* Supervisor: Adjunct Professor Arne Skretting.

Dag Werner Breiby, *Neutron Guide for a New SANS Instrument at IFE, Kjeller.* Supervisor: Professor Emil J. Samuelsen.

Erik Magnus Bruvik, *Measuring Small Vibrations Using Digital TV-Holography.* Supervisor: Associate Professor Jesus Valera

Astrid Marie Nesbø Dahl, *Temperature in the arctic stratosphere retrieved from lidar measurements in Ny-Ålesund.* Supervisor: Associate Professor Berit Kjeldstad.

Dag Magnus Eriksen, *Simulation of dispersion with FLACS.* Supervisor: Professor Helge I. Andersson

Cato Fagermo, *Hardness Measurements in Noble Metals System with Atomic Force Microscopy.* Supervisor: Anne Borg.

Andres Gudmund Frøseth, *Energy Production in the Formation of a Finite Thickness Cosmic String.* Supervisor: Professor Ragnvald Høier.

Erik Marius Gamborg, *Electric Field Distribution in an Electrical Discharge Creeping on an Insulating Plane.* Supervisor: Professor Reidar S. Sigmond.

Kjetil Gjerde, *The Development of OperCon – a Spacecraft Orbit Control Software for the SkyBridge Satellite Constellation.* Supervisor: Professor Tor Ytrehus.

Pål Erik Goa, *Atomistic Modelling of Carbon Structures. A Comparison of Non-Orthogonal Tight Binding and Density Functional Theory.* Supervisor: Professor Ragnvald Høier.

Bjørn Anton Graff, *Capillary Permeability of Albumin in Human Melanoma Xenografts.* Supervisor: Adjunct Professor Einar K. Rofstad.

Hans Rossavik Gundersen, *Implementation and Comparison of Phase Unwrapping Techniques for a Shape Measuring Instrument.* Supervisor: Associate Professor Jesus D. Valera.

Jørgen Hals, *Numerical Simulation of Ocean-Wave Energy Conversion with Particular Attention to an Oscillating Water Column*. Supervisor: Professor Johannes Falnes.

Mona Helene Hansen, *Modulation of CD14 Studied by Confocal Microscopy in SW480 Cells Stimulated by LPS*. Supervisor: Professor Tore Lindmo.

Fredrik Hansteen, *Measurement of Dew Point by Means of Surface Plasmon Polariton Resonance Technoques*. Supervisor: Professor Ola Hunderi.

Nils Erland Leinebø Haugen, *Adveksjons-dominert masseoverføring til svarte hull*. Supervisor: Professor Erlend Østgaard.

Øyvind Haugen, *3D Blind Deconvolution of Seismic Data*. Supervisor: Professor Jan Myrheim.

Eivind Asbjørn Holvik, *Opto-Dynamic Inspection of Material Defects*. Supervisor: Professor Ole J. Løkberg.

Torkjell Huse, *New Instruemnation for Quantitative Measurements of Biopolymer Electrooptic Properties*. Supervisor: Professor Arnljot Elgsæter.

Charanjit Singh Jhutti, *Time resolved multichannel spectroscopy of molecular triplet states*. Supervisor: Professor Kalbe Razi Naqvi.

Stein Johansen, *Development of software and testing of Gill's sonic sensor Windmaster*. Supervisor: Associate Professor Jørgen Løvseth

Lars Gjellan Kjølseth, *Single Fiber Multi-Mode Optical Fiber Interferometer for Deflection Analysis in Harsh Environments*. Supervisor: Ole J. Løkberg.

Tore Kjørsvik, *A UHV Diffraction Camera with Energy Filter for Convergent Beam RHEED and TED*. Supervisor: Professor Ragnvald Høier.

Magnus Korpås, *Optimisation of Thermal Performance in Power Plants*. Supervisor: Professor Johan S. Høye.

Amund Krane, *Analysis of Flow-Volume Curves from Pediatric Pulmonary Testing, with Regard to Curve Shapes*. Supervisor: Professor Bjørn T. Stokke.

Øyvind Kvam, *Gluon Bremsstrahlung i dyp uelastisk spredning*. Supervisor: Haakon Olsen.

Martin Lam, *Late Effects of Radiotheraphy for the Visual Pathway*. Supervisor: Professor Anna Midelfart.

Hans Freddy Atterås Larsen, *A Quantitative Methodology for Determination of Residual Oil Saturation in a Reservoir Rock from Pulsed Neutron Capture – Applied on TDT Log Data from Oseberg*. Supervisor: Professor Helge R. Skullerud.

Jørn Tore Larsen, *Wave Group Theory in Modelling Turbulent Wave Boundary Layers*. Supervisor: Professor Iver Brevik.

Simen Berg Lutnæs, *Experimental Studies of Water Intercalation in a Layered Silicate System*. Supervisor: Professor Alex Hansen.

Geir Myrvågnes, *Characterization of Sb-Based Semiconductors Using X-Ray Diffraction and Transmission Electron Microscopy*. Supervisor: Professor Ragnvald Høier.

Jan Petter Mæhlen, *Seiberg-Witten dualitet*. Supervisor: Professor Kjell Mork.

Lars Audun Nornes, *Gamma-Ray Bursts*. Supervisor: Professor Erlend Østgaard.

Ståle Leigland Nybakk, *Measurement of Hydraulic Conductivity and Compliance in Experimental Tumours*. Supervisor: Adjunct Professor Einar K. Rofstad.

Hallstein Otnes, *Instrumentation of a System for Light Scattering Measurements and Ellipsometry*. Supervisor: Professor Ola Hunderi.

Didrik Paus, *The Effect of Collagenase on Diffusion of Dextrans in Multicellular Spheroids*. Supervisor: Associate Professor Catharina Davies

Lise Lyngsnes Randeberg, *Specially Designed Optical Equipment for Clinical Skin Measurements in Infants; Skin Color Evaluated with CIE Color Coordinates and Visualized on Monitor*. Supervisor: Professor Tore Lindmo.

Atle Sinstad Rasmussen, *Fiberoptisk nær infrarød spektroskopi for ikke destruktiv* *transfleksjonsmålinger.* Supervisor: Morten Eriksrud.

Magnus Reigstad, *Kinetics of Hydrogenation of Crudes Containing Naphthenic Acids.* Supervisor: Professor Ola Hunderi.

Atle Rognmo, *Ceometric Overlap Function for ALOMAR Ozone Lidar.* Supervisor: Professor Ole J. Løkberg.

Frøydis Romundset, *AFM Studies of Deposited Laponite Clay Surfaces.* Supervisor: Professor Alex Hansen.

Tor Egil Rødahl, *Perturbasjoner av vannregulering hos planter. Et eksperimentelt og teoretisk studium.* Supervisor: Professor Anders Johnsson.

Håvard Bunes Sandvik, *Evolution of a Network of Cosmic String Loops.* Supervisor: Professor Iver H. Brevik.

Tonje Sekse, *The Elastic Properties of β-(1,3)-D-Glucan Stimulated Human Monocytes Determined by AFM.* Supervisor: Professor Bjørn T. Stokke.

Anna Marås Sindre, *Characterization of Nitrided Layers in Stainless Steels.* Supervisor: Professor Ragnvald Høier.

Ronny Sletteng, *Realisering og karakterisering av avstembare fiberlasere.* Supervisor: Professor Anders Johnsson.

Therese Stokke, *Applications of Measured Gamma Ray Transmission in Positron Emission Tomography (PET) on a Dual Head Gamma Camera: A Study of Different Methods for Attenuation Correction and Coregistration with CT Image Series.* Supervisor: Adjunct Professor Arne Skretting.

Ulrik Schou Thisted, *LOCV Calculations of the Ground-State Energy and Magnetic Susceptibility of Liquid Helium-3.* Supervisor: Professor Erlend Østgaard.

Marit Thorsen, *Role of Genetic Polymorphisms of Cytogenetic Effects in Relationship to Occupational Exposure and Lifestyle Factors of Workers.* Supervisor: Associate Professor Catharina Davis.

Steinar Tveiten, *Pulse Inversion Versus Second Harmonic Ultrasound Imaging – An in Vitro Comparison Study.* Supervisor: Professor Bjørn Torger Stokke.

Øystein Vatland, *Two Phase-Flow of Oil and Water in Vertical and Deviated Pipes.* Supervisor: Professor Arnljot Elgsæter.

Ann Olaug Vorren, *Blood Flow in Cervix Tumours Measured by Magnetic Resonance Imaging.* Supervisor: Adjunct Professor Einar K. Rofstad.

Liv Helen Vaagland, *^{31}P NMR-studier av propionibacterium acnes celler.* Supervisor: Professor Anders Johnsson.

Ivar Wærnhus, *Developing a Magneto-Optical Measurement System for Superconductors.* Supervisor: Professor Kristian Fossheim.

Ståle Ølberg, *Measurement of the Doxe Distribution from External Irradiation of a Lung Phantom by Ferrous Sulphate Gel and MRI.* Supervisor: Adjunct Professor Arne Skretting.

Vemund Halmø Aarstrand, *Nonlinear Laser Spectroscopy of Rare-Earth Ions.* Supervisor: Ola Hunderi.

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CURRICULUM

Siv.ing. study, 1th and 2nd year. *Student attendance*:	**1992**
Physics for Civil and Environmental Engineering	139
Laboratory for Physics Students 1	163
Laboratory for Physics Students 2	136
Physics for Geology and Petroleum Students	141
Physics for Electronics Students	245
Physics for Chemistry and Metallurgy Students	187
Physics for Computer Students	200
Physics for Machine Technology Students	204
Physics for Marine Students	80
Laboratory for Physics Students 3	124
Laboratory for Physics Students 4	88
Mathematical Physics	89
Physics and Geophysics	126

Siv.ing. study, 3rd year.	**544**
Physics 2 for Electronics Students	173
Experimental Physics 1	50
Statistical Physics	35
Electromagnetic Theory	35
Atomic and Molecular Physics	49
Optics	72
Solid State Physics 1	53
Physics of Charged Particles	21
X-ray Crystallography	9
Cell Biology 1	21
Cellular Biophysics	26

Siv.ing. study, 4th year.	**299**
Global Transfer in Nature	25
Physics and Energy	
Quantum Mechanics 2	22
Relativistic Quantum Mechanics	7
Classical Transport Theory	24
Theory of Classical Fields	15
Nuclear Physics	7
Solid State Physics 2	17
Quantum Theory of Solids	7
Diffraction and Microstructure	21
Structure and Properties of Crystals	7
Microstrukture and Mechanical Properties	3
Physiology with Pathology	22
Physiology with Pathology	11
Molecular Biophysics	19
Biophysics (special)	16
Biomedical Technology	16
Physics Project	38
Biophysics Project	14

Dr.ing. study.	**43**
Technical Optics 1	7
Characterisation of Solid Surfaces – Surface Physics	9
Photon Physics	3
Ocean-Wave Energy	2
Phase Transitions and Critical Phenomena	14
Crystallography – Scattering and Diffraction	1
Light and Neutron Spectroscopy	2
Application of Symmetry Groups in Physics	6
Computational Physics	1
Advanced Statistical Physics	4
Dosimetry of Ionizing Radiation	2

Cand.mag. study.	**249**
User Course in Physics	42
General Physics I	44
General Physics II	20
Mechanics	17
Electricity and Magnetism	15
Quantum Physics and Statistical Physics	28
Physics Didactics	18
System Dynamics	2
Electronics I	5
Fluid Mechanics	7
Energy and Environmental Physics	9
Biophysics I	6
Classical Mechanics and Elektrodynamics	5
Quantum Mechanics I	9
Astro Physics I	22

Cand.scient. study.	**73**
Measuring Sensors and Transducers	12
Electronics II	2
Signal Analysis	12
Fiber Optical Components and Measuring Systems	8
Matematics and Geophysics	6
Biophysics II	1
Quantum Mechanics II	3
Astro Physics II	5
Many Particle Physics I	1
Particle and Nuclear Physics I	8
Particle and Nuclear Physics II	4

Dr.scient. study.	**10**
Many Particle Physics II	1
Quantum Field Theory	8
Quantum Flavour and Quantum Chromodynamics	1

Other subjects.	**69**
Star Atmospheres	1
Black Holes	1
Light, Sight, Colour	1
Cosmology and Exobiology	30
Physics of the Atmosphere	9
White Dwarfs	5
Space Technology	22