INSTITUTE

OF

THEORETICAL PHYSICS

Faculty of Physics

Warsaw University

1998-1999

Warsaw 2000

INSTITUTE OF THEORETICAL PHYSICS

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Number of staff members (Dec. 31, 1999):

Academic teachers: 49
Librarians: 5
Secretaries: 2
Technical personnel: 1
Operating personnel: 1

DIVISIONS

FS Division of Field Theory and Statistical Physics
RG Division of General Relativity and Gravitation
MP Division of Mathematical Physics
NS Division of Nuclear Structure Theory
EP Division of Theory of Elementary Particles and Interactions
HL Division of Theory of Hadrons and Leptons
SS Division of Theory of Solid State

Editor and cover picture: Krzysztof Pachucki, IFT UW, 2000

CONTENTS

1 FOREWORD

It became a tradition at the Faculty of Physics of Warsaw University that its two largest institutes, Institute of Experimental Physics and Institute of Theoretical Physics, organize at alternate years a symposium in which their main research topics and achievements are presented to the academic community. In December 1999 the Institute of Theoretical Physics organized its third Symposium "IFT UW-99". This prompted us to publish the present report which contains information about the Institute and its activities and achievements in 1998–1999, i.e., in the period between our second and the third symposium.

2 PROFILE OF THE INSTITUTE

The Institute of Theoretical Physics is, after the Institute of Experimental Physics, the second largest among the five units within the Faculty of Physics at Warsaw University. It is the largest institution of theoretical physics in Poland. At the end of 1999 it employed 49 academic teachers whose duties are scientific research and/or teaching. 33 postgraduate students of the Faculty of Physics worked on their Ph.D. theses and assisted in teaching in our Institute. The administration, library, technical and operating personnel included 9 persons.

As a university unit the Institute combines the scientific activity with teaching. For this reason the research conducted at the Institute covers a comprehensive range of modern theoretical physics starting from the theory of elementary particles and interactions including gravitation, through the quantum theory of nuclei, atoms and condensed matter, statistical theory of macroscopic systems, up to the theoretical astrophysics. These investigations of physical systems are accompanied with studies on fundamental problems of quantum mechanics, mathematical problems of the classical and quantum field theory and nonlinear systems. So comprehensive scope of research requires division of the Institute into smaller research groups. There are 7 Divisions within the Institute at present. They carry on the research and also teaching for graduate (specialization in various domains of theoretical physics) and postgraduate students. More detailed information on particular subjects of research and achievements in 1998–1999 is presented below for each Division separately. According to the classification of the Polish State Committee for Scientific Research (KBN) in 1998–1999 the Institute, within the Faculty of Physics, was placed in the highest category I in physics together with 6 other institutions. An intense collaboration of members of the Institute with many international scientific institutions and foreign universities confirms on the one hand its high scientific standard and allows for keeping it on the other.

3 TEACHING ACTIVITIES OF THE INSTITUTE

Concerning teaching, the Institute provides lectures and courses on Calculus (Mathematics A for freshmen and sophomore), Mathematical Methods in Physics, Numerical Methods, and basic courses of theoretical physics (Classical and Quantum Mechanics, Classical Electrodynamics and Statistical Physics) for undergraduate students. The subjects are not assigned to particular lecturers or Divisions. The rule is that every lecturer can deliver by turns different lectures.

It is otherwise with specialized and monographic lectures on various topics in theoretical and mathematical physics for graduate and postgraduate students. These are delivered by specialists in that domain and assigned to particular Divisions. Only some of these lectures are in English, but we presume that the number of such lectures will increase in the future. The majority of specialized and monographic lectures are in Polish. They cover the whole of theoretical physics, like for instance mathematical methods in physics (soliton theory), geometry and the general theory of relativity, elementary particle physics and quantum field theories, theory of the nuclear structure, solid state and atomic physics, quantum optics, electrodynamics and statistical physics.

Apart from lectures two student's seminars in theoretical physics for undergraduate and graduate students are conducted, where participants are supposed to prepare a lecture under the supervision of a senior physicist of the Institute, and present it in front of other students attending these seminars. In this way young people actively take part in the educational process, what fosters an early engagement in scientific researches, and in some cases results in publishing their work in international scientific journals prior to receiving M.Sc. degrees. The employees of the Institute supervise other forms of educational activities. For instance some of our colleagues organize Workshops for pupils of grammar schools from different parts of Poland and supervise the activity of the Student Group of Nonlinear Physics, that is even publishing its own Bulletin with student's original scientific papers.

Due to a substantial increase of the number of students studying physics in the Faculty of Physics at Warsaw University the teaching load of employees and Ph.D. students of the Institute has recently jumped up significantly, by around 30%. In the last two academic years, 1997/98 and 1998/99, 34 students got their M.Sc. degrees, 9 got the B.Sc. (*licentiate*) degrees, 3 post graduate students defended their Ph.D. theses, and 4 scientists received the D.Sc. (*habilitation*) degree. At present employees of the Institute supervise the scientific work of 33 postgraduate (Ph.D.) students, which got stipends from the University.

4 SEMINARS

The important part of the Institute activity which combines research with teaching are regular specialized seminars organized in the Institute. These seminars cover all branches of theoretical physics practiced in the Institute. During the academic years 1997/98 and 1998/99 the following seminars were organized:

- Seminar on Chaos and Nonlinearity
- Seminar on Condensed Matter Physics
- Seminar on High Energy Physics
- Seminar on Geometry of Space-time
- Seminar on Geometry and Nonlinearity
- Seminar on Computer News
- Seminar on Elementary Interactions
- Seminar on Nuclear Spectroscopy
- Seminar on Astrophysics
- Seminar on Optics
- Seminar on Statistical Physics
- Seminar on Theory of Atomic Nuclei
- Seminar on Theory of Relativity

5 LEOPOLD INFELD SEMINAR

A special role among the seminars is played by the Leopold Infeld Seminar (*konwersatorium*). It was established by Professor Leopold Infeld, the founder and the first director of the Institute, and has the tradition of almost 50 years. It is the seminar for the entire community of Warsaw's theoretical physicists where general, actual and hot problems of theoretical physics are discussed. The language of the seminar is English or Polish but English is chosen when people who do not understand Polish are in the audience.

At present time it is coorganized by the Institute of Theoretical Physics at Warsaw University, the Center of Theoretical Physics of the Polish Academy of Sciences and the Department of Nuclear Theory of the Andrzej Sołtan Institute for Nuclear Studies (since 1999). Traditionally, it is chaired by the heads of the above institutions (i.e., by Stanisław G. Rohoziński, Kazimierz Rzążewski and Grzegorz Wilk in 1998–99).

LECTURES GIVEN ON THE LEOPOLD INFELD SEMINAR IN 1997/98 AND 1998/99

09.10.1997 Peter Mazur, Leid University
THE HISTORY OF SYMMETRY RELATIONS FOR IRREVERSIBLE PROCESSES

23.10.1997 Krzysztof Wódkiewicz, IFT UW
QUANTUM TOMOGRAPHY

30.10.1997 Bogdan Mielnik, IFT UW
THE CLASSICAL MODEL OF SCHRÖDINGER EQUATION

20.11.1997 Piotr Rączka, IFT UW
WHAT IS THE VALUE OF THE QCD COUPLING CONSTANT?

04.12.1997 Jan Blinowski, IFT UW
THE COUPLING BETWEEN MAGNETIC LAYERS SEPARATED BY A NONMAGNETIC MATERIAL

08.01.1998 Adam Sobiczewski, IPJ
PROPERTIES AND SYNTHESIS OF SUPERHEAVY ELEMENTS

22.01.1998 Iwo Białynicki-Birula, IFT UW and CFT PAN
CAN PHOTONS BE LOCALIZED?

19.02.1998 Reinhard Meinel, Theoretisch-Physikalisches Institut, Jena
ROTATING DISKS AND BLACK HOLES

26.02.1998 Hermann Nicolai, MPI, Potsdam
SUPERMEMBRANES AND MATRIX MODELS

12.03.1998 F. H. M. Faisal, Universität Bielefeld
DETERMINISTIC QUANTUM CHAOS AND TIME-REVERSAL SYMMETRY

26.03.1998 Tomasz Werner, IFT UW
FRONTIERS OF NUCLEAR STRUCTURE

23.04.1998 Krzysztof Pachucki, IFT UW
PERTURBATIVE CALCULATIONS IN THE QUANTUM ELECTRODYNAMICS OF BOUND STATES

07.05.1998 Bogdan Cichocki, IFT UW
WHAT A GUY WE HAD — QUESTION OF MARIAN SMOLUCHOWSKI

21.05.1998 R. Ellis, CERN
THE FUTURE OF ACCELERATOR PARTICLE PHYSICS

27.05.1998 Francoise Brochard, Universite Paris VI and Institut Curie
DYNAMICS OF DEWETTING

Pierre-Gilles de Gennes (Nobel'91), Ecole Superieure de Physique et Chimie Industrielles
PERSPECTIVES FOR ARTIFICIAL MUSCLES

08.10.1998 Jerzy Przeszowski, Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw
IS THE LIGHT-FRONT QCD A TRUE GAUGE THEORY?

15.10.1998 Wilhelm Becker, Max-Born-Institute, Berlin
MATHEMATICAL MODELING OF THE STOCK MARKET: WHAT IS THE FAIR PRICE OF AN OPTION?

29.10.1998 J. Cieśliński, University of Białystok
SOLITON SURFACES, THE DARBOUX-BAECKLUND TRANSFORMATION AND THE CLIFFORD ALGEBRAS

19.11.1998 Andrzej Holas, IChF PAN
THE DENSITY FUNCTIONAL THEORY — A UNIVERSAL TOOL OF PHYSICISTS AND CHEMISTS (NOBEL'98 PRIZE FOR WALTER KOHN)

26.11.1998 J. Indekeu, Catholic University of Leuven
WETTING AND SUPERCONDUCTIVITY

10.12.1998 Karol I. Wysokiński, Institute of Physics, Uniwersytet im. M. Curie-Skłodowskiej w Lublinie
THE FRACTIONAL QUANTUM HALL EFFECT (NOBEL'98 IN PHYSICS)

07.01.1999 Bernard F. Schutz, Albert Einstein Institut, Potsdam
DEVELOPING GRAVITATIONAL WAVE ASTRONOMY

21.01.1999 Dariusz Gątarek, Instytut Badań Systemowych PAN i BRE Bank, Warszawa
O TEORII BLACKA, SCHOLESA I MERTONA WYCENY OPCJI

4.03.1999 Bohdan Grządkowski, IFT UW
VIOLATION OF THE CP SYMMETRY IN LIGHT OF LOOKING FOR A NEW PHYSICS

18.03.1999 Marek Kuś, CFT PAN
QUANTUM ERROR CORRECTING CODES

08.04.1999 Knud Taulbjerg, Arhus University, *PECULIAR PROPERTIES OF TWO AND THREE BODY COULOMB INTERACTIONS*

22.04.1999 Marek Demiański, IFT UW
THE COSMOLOGICAL CONSTANT - A PHANTOM OR REALITY

06.05.1999 Jan Kalinowski, IFT UW
NEW PHYSICS BY MEANS OF NEW ACCELERATORS

20.05.1999 Emmanuel A. Paschos , Dortmund
MEDIEVAL ASTRONOMY: ANALYSIS OF BYZANTINE MODELS FROM A. D. 1300

6 THE INFELD CENTENNIAL MEETING

To celebrate Leopold Infeld centennial a group of his former students and collaboratores organized at the Institute of Theoretical Physics, University of Warsaw the Infeld Centennial Meeting. The Meeting was held in Warsaw on June 22 - 23, 1998. Among the speakers were Sir Herman Bondi, Sir Roger Penrose, I. M. Khalatnikov, I. D. Novikov, J. Stachel, T. Richmond, I. Bialynicki Birula, R. Gajewski and W. Tulczyjew. Proceedings of the Meeting were published in a special issue of the Acta Physica Polonica Vol. B30, Number 10 (October), 1999.

7 SYMPOSIUM IFT UW-99

Symposium IFT UW-99 has been organized in the Institute on December 10–11, 1999. In the 9 lectures topics related to main research subjects and achievements in 1998–1999 of the Institute have been presented in a popular way to nonspecialists, and students. The 2 additional talks presented topics of research carried out in two smaller units of the Faculty, the Institute of Geophysics and the Chair of Mathematical Methods in Physics.

PROGRAM OF THE SYMPOSIUM

Friday, December 10

Morning session
Chairperson: Jacek Dobaczewski

- Marek Demiański, *The Universe at different wavelengths*
- Wojciech Satuła, *Nuclear structure at the borders of Mendeleev periodic table*

Midday session
Chairperson: Witold Bardyszewski

- Jakub Tworzydło, *Quantum dots*
- Bogdan Cichocki, *Suspensions — a challenge for statistical physics*

Afternoon session
Chairperson: Stefan Pokorski

- Piotr Chankowski, *The Standard Model and masses of neutrinos*
- Maria Krawczyk, *Higgs particle*
- Jacek Jasiak, *Do Quarks Obey the First Newton's Principle ?*

Saturday, December 11

Morning session
Chairperson: Antoni Sym

- Adam Doliwa, *Integrable nonlinearities in differential and discrete geometry*
- Szymon P. Malinowski, *Computational Fluid Dynamics in Meteorology: Weather Forecasts and Beyond*

Midday session
Chairperson: Jerzy Kamiński

- Jan Dereziński, *Mathematical aspects of the Fermi Golden Rule*
- Konrad Banaszek, *How to see the quantum state?*

ABSTRACTS OF THE LECTURES

- **Marek Demianski**, *The Universe at different wavelengths*
  A general review of basic astronomical discoveries made at different wavelengths was presented. For a very long time optical observations were the only source of information about the Universe. Invention of the first optical telescope by Galileo dramatically increased the scale of the observable Universe. With present day large optical telescopes and the Hubble Space Telescope we observe galaxies at their very early stage of evolution. Intricate structure of the large scale distribution of matter was discovered with galaxies forming clusters of galaxies, filaments and walls leaving large voids practically without luminous matter. Observations of the Universe at radio wavelengths helped to discover neutron stars and the cosmic microwave background radiation. Development of satellite X-ray observatories opened up a new and quite unexpectedly very exciting window to look at the Universe. X-ray observations supplied the first indications of the existence of stellar mass black holes in X-ray binary systems and supermassive black holes in active galactic nuclei. We are now anxiously waiting for new windows which will open up soon to look at the Universe in neutrinos and in gravitational waves.

- **Wojciech Satuła**, *Nuclear structure at the borders of Mendeleev periodic table*
  The recent technological progress allows already nowadays [or soon will allow] for exploration of the borders of nuclear stability. Under extreme conditions of temperature, density, isospin or angular momentum atomic nuclei are expected to reveal new phenomena, which are sensitive to exotic components of nuclear forces. It rises hopes for better understanding of the nuclear effective interactions as well as the nuclear many-body methods.
  In my talk I went to the extremes of large isospins [very neutron-rich systems] and very high angular momenta. I started with discussion of the main properties of nuclear superconductivity in diluted neutron matter. This problem is of relevance

for both the dynamics of neutron stars and for neutron-rich atomic nuclei where extended skin regions are expected to appear. Next, I have briefly discussed the phenomenon of magic gap melting. This theoretically predicted phenomenon of smooth disappearance of shell structure is expected to show up in weakly-bound, neutron-rich nuclei and it is of importance for nucleosynthesis of heavy elements in the so called rapid neutron capture process which takes place during supernova explosion. In fact, recent measurements of the r-process solar system abundances of heavy elements seems to support the gap-melting scenario.
In the second part of my talk I have discussed selected aspects of superdeformed [ellipsoidal shape of 2:1 axis ratio] nuclei. Behind formation of the superdeformed minima hides certain simple mechanism of clustering. This mechanism appears to be related to the degeneracy pattern of single-particle nuclear levels which is similar to that shown by the deformed harmonic oscillator of rational axis ratio. Indeed, the nuclear mean-fields reflect certain dynamical [approximate] symmetry which is called pseudo-SU(3). The most extreme case of manifestation of this symmetry is the phenomenon called identical bands. The pseudo-SU(3) symmetry, although does not fully explain band twinning, is crucial for understanding of their identicality. The interesting aspect of the story is that physical roots of the pseudo-SU(3) symmetry grow from the relativistic background.

- **Jakub Tworzydło**, *Quantum dots*
  The progress of semiconductor technology and an associated development in microelectronics has already lasted for four decades. Miniaturization of electronic elements has so far followed an exponential law formulated by Moore in the sixties. At present, extrapolation of this trend predicts that around year 2020 scale of microdevices will be so small, that quantum effects should become important. Unexpected properties of electronic elements in so called nanoscale (with sizes not bigger then hundred nanometers) are tested now in laboratories with the use of quantum dots. Quantum dots are usually formed by applying external electrodes to a semiconductor heterostructure. Number of conducting electrons in a quantum dot may be precisely tuned from just a few to a few hundred. In my lecture I presented some fundamental effects of electron transport in such systems. I explained the mechanism of Coulomb blockade, which makes possible detection of single electron levels. Main features of the Coulomb blockade spectrum are explained in a model of constant interactions. This model predicts a shell structure of many-electron states and has recently been confirmed experimentally. I introduced some notions of random matrix theory and compared theoretical predictions with statistics of levels in a chaotic dot. In a final part of my talk I discussed open theoretical and experimental problems of this research field.

- **Bogdan Cichocki**, *Suspensions — a challenge for statistical physics*
  It is well known that suspensions are of great interest for their technological applications. In order to understand their properties it is necessary to use a statistical description. This is a difficult task. However, practical applications should not

be the only reason for such an interest. Many phenomena important for statistical physics which are unobservable in atomic systems can be observed in colloidal suspensions due to much longer time and length scales.

- **Piotr Chankowski**, *The Standard Model and masses of neutrinos*
  After a brief outline of our best physical theory - the Standard Theory of elementary particle interactions and having recalled its main successes, we shortly present results of recent neutrino experiments which strongly suggest that the theory should be extended to include neutrino masses. We show that such an extension is very natural and does not spoil those predictions of the Standard Theory which are in very good agreement with other experiments. It suggests, however, that the present theory should be considered as a so called effective theory, i.e. a theory which is only (although a perfect one as far as predictions of physical phenomena at currently accessible energies are concerned) an approximation to an as yet unknown more fundamental underlying theory.

- **Maria Krawczyk**, *Higgs particle*
  The concept of the Higgs mechanism in the Standard Model, the present theory of elementary particles, is discussed. The Higgs mechanism is crucial for a consistent description of the basic interactions and for generating the masses of the fundamental particles. The search for the corresponding Higgs boson is in the focus of all existing high energy experiments; at present they provide the lower limit for the SM Higgs boson mass of 110 GeV/c^2. The Higgs boson is the only lacking ingredient of the Standard Model. If found it may shed light on the underlying more fundamental theory valid also at much higher energy scales, of which the present theory is only the "low-energy" effective approximation.

- **Jacek Jasiak**, *Do Quarks Obey the First Newton's Principle ?*
  The starting point is the fact, that the motion of a particle with no external force acting on it, is on the quantum field theory level described by the particle propagator S. If S differs (due to self–interaction and interaction with the vacuum) nontrivially from the free (totally noninteracting) propagator, one may expect that classical motion of the particle which it describes differs from uniform motion on a straight line. This fact is in more detail examined in the case of the propagator introduced by M. Stingl and rewritten by J. M. Namysłowski in the form $S(p) = \left(\gamma \cdot p - m + \chi^3/M/(\gamma \cdot p - M)\right)^{-1}$. Such a propagator obeys many interesting features: it does not allow for asymptotic quark states, but even in the case of nonconfining quark-antiquark potentials (vanishing at infinity), one may obtain bound states and no disperse states.

- **Adam Doliwa**, *Integrable nonlinearities in differential and discrete geometry*
  Going beyond the linear approximations to the real models one encounters surprising and complex effects that would never be anticipated by a scientist trained only in linear techniques. Prominent examples of such phenomena include bifurcation, chaos and solitons.

Certain nonlinear differential equations can be however fully solved by the so called spectral transform. Examples of such *integrable equations* are the Korteweg–de Vries, the nonlinear Schrödinger and sine-Gordon equations. An interesting feature of these equations is their close relationship with classical differential geometry. The integrable geometry is the theory of submanifolds described by nonlinear integrable equations. In particular, various transformations between surfaces, studied extensively in the XIX-th century by Bianchi, Darboux, Ribaucour and others, correspond to the celebrated Bäcklund transformations between solutions of the equations.
In recent years, there has been made considerable progress in developing the discrete (difference) versions of various topics in physics and mathematics. Often the discrete models are considered as more fundamental then their continuous analogs. For example, some attempts to quantize the theory of gravity strongly suggest that in a very small scale the space-time may exhibit a discrete structure (such a speculation can be found also in the famous Riemann's habilitation lecture). During last few years many important results of the classical integrable geometry have been generalized to the discrete level. In particular, it was shown that the fundamental role in the integrable discrete geometry, and in the whole soliton theory, is played by multidimensional lattices of planar quadrilaterals.

- **Szymon P. Malinowski** (Institute of Geophysics), *Computational Fluid Dynamics in Meteorology: Weather Forecasts and Beyond*
  In the lecture a short summary of recent achievements in numerical weather prediction and modeling of atmospheric flows conducted at the Institute of Geophysics (IGF) and Interdisciplinary Centre for Mathematical and Computational Modeling (ICM), Warsaw University, was presented. The talk began with the brief historical introduction to computational fluid dynamics in meteorology. The famous Richardson's attempt to solve numerically equations of atmospheric dynamics and thermodynamics from 1919 was mentioned. Later achievements of Charney and Eliassen with the first operational numerical weather prediction from fifties were underlined. Finally a list of problems which have to be handled or solved in order to give a numerical weather forecast:

  – form of equations
  – parameterizations of sub-scale processes (turbulence)
  – parameterizations of processes not solved directly (microphysics, radiation, soil and water)
  – boundary conditions
  – discretization or decomposition, numerical methods
  – computational domain and grid
  – data assimilation
  – computational code and machine architecture

– post-processing and visualization

was presented and discussed. In the second part of the talk a hydrostatic numerical model used for the mesoscale weather forecasting at ICM was presented. Examples of model outputs in form of weather maps and meteograms were shown and problem of predictability and quality of the forecast was addressed. The last part of the presentation was devoted to recent numerical simulations performed with the nonhydrostatic experimental EULAG model, developed at the National Center for Atmospheric Research by the scientists who had been connected with our group. Examples of two-dimensional modeling of the Kelvin-Helmhoz instability as well as dry and wet mountain waves were shown. Finally three-dimensional LES (Large Eddy Simulations) of convection in the troposphere and DNS (Direct Numerical Simulations) of small-scale turbulent mixing of clouds were presented.

- **Jan Dereziński** (Chair of Mathematical Methods in Physics), *Mathematical aspects of the Fermi Golden Rule*
  Small quantum systems (eg. atoms) interacting with bosonic fields (eg. photons) can be sometimes described by simplified Hamiltonians called the generalized spin-boson or Pauli-Fierz Hamiltonians. In the absence of interaction they have embedded eigenvalues. When the interaction is present, most of these eigenvalues usually disappear – except for the ground state in the 0-temperature case and the KMS state in the positive temperature. It is often possible to analytically continue certain matrix elements of the resolvent. In the zero temperature case, the domain of analyticity typically has cuts. The tips at the end of these cuts are physically interpreted as resonances. In the positive temperature case, the domain of analyticity often contains a horizontal strip below the real axis, except for some poles. These polesare called resonances. In the positive temperature case one can rigorously show the exponential decay of certain matrix elements. Their decay rate is given by the imaginary part of the resonances.

- **Konrad Banaszek**, *How to see the quantum state?*
  In quantum mechanics, the complete information on the quantum state is contained in the wave function. Given the wave function, one can calculate all the properties of the system. Usually, only few of these properties are measured in a typical experiment. However, one may pose a more fundamental question: is it possible to reveal experimentally the complete information on the quantum state? Such a problem is currently of practical interest in many areas of science: appropriately prepared quantum states are necessary in novel technologies such as quantum cryptography and quantum computing.
  In this presentation, we review the measurement of the quantum state using the Wigner phase space distribution function. The Wigner function characterizes the quantum state in the form which is analogous to a classical phase probability space distribution. The first practical method developed for measuring the Wigner function was quantum tomography. It is based on the observation that marginal distributions of the Wigner function describe distributions of linear combinations of posi-

tion and momentum, and can be directly measured. The complete Wigner function is reconstructed from these data using the filtered back-projection algorithm used in medical imaging. Such a sophisticated numerical processing of experimental data is avoided in the direct method for measuring the Wigner function. This method, developed recently by us at the Warsaw University, provides the value of the Wigner function at a phase space point defined by some physical parameters of the experimental setup. By changing these parameters, one can scan the phase space point-by-point, and thus obtain the complete picture of the quantum state.

8 DIVISION OF FIELD THEORY AND STATISTICAL PHYSICS

Head: Prof. Jarosław Piasecki
Academic Teachers: Prof. Iwo Białynicki-Birula, Dr hab. Bogdan Cichocki, Dr hab. Jerzy Kamiński, Prof. Marek Napiórkowski, Dr hab. Krzysztof Pachucki, Dr Krzysztof Rejmer, Prof. Krzysztof Wódkiewicz
Postgraduate Students: 9

SCIENTIFIC ACTIVITIES

- hydrodynamic interactions
- interfacial phase transitions, wetting, capillarity
- critical phenomena
- the structure of capillary-wave Hamiltonians
- interaction of atoms with strong laser fields
- multiphoton ionization
- QED effects in hydrogenic and two–electron atoms
- physics of light exotic atoms
- theory of bound states in relativistic QED

SCIENTIFIC ACHIEVEMENTS

- A rigorous study of the dynamics of a one-dimensional, gravitationally interacting sticky gas has been performed at the microscopic level. It has been demonstrated that at a characteristic finite time a single macroscopic mass was formed, surrounded by a dust of nonextensive fragments. In the continuum limit this corresponds to a single shock creating a singular mass density. The statistics of the remaining fragments obeys the Poisson law at all times following the shock.
- The systematic study of the adiabatic piston problem has been performed within the framework of the Boltzmann kinetic theory. In the infinite volume case it has been shown that at equal pressures on both sides of the adiabatic movable partition (piston) the temperature difference induced a non-zero drift velocity oriented toward the region of higher temperature. A remarkable macroscopic effect of the asymmetry of fluctuations has been thus discovered, resulting (despite the mechanical equilibrium) in a macroscopic motion. The phenomenon is present both in the case where the mass of the piston is equal to the mass of the surrounding gas atoms, and in the case of massive piston (Brownian motion limit).

- A new Floquet-Bloch theory for interaction of intense laser fields with periodic structures has been developed and applied to above-threshold surface-emission of electrons as well as to high harmonic generation from thin crystals. The results of simulations of photoelectron spectra show: (i) appearance of above-threshold photoelectron bands (ii) envelope-modulation of the photoelectron spectrum, and (iii) fine splitting of the above-threshold surface-emission bands into sub-bands. The results have been compared with that obtained from the free-electron Sommerfeld model showing large discrepancies. Formation of 'multiple plateaus' in high harmonic generation with thin crystals interacting with intense laser fields has also been predicted.

- The effective hamiltonian approach to bound state QED has been developed and the long standing problem of relativistivc corrections to positronium energy levels of order $O(\alpha^4)$ has been solved. Results indicate a strong disagreements with measurements of positronium hyperfine structure.

- Theory of energy levels of muonic hydrogen has been worked out, allowing for the determination of proton charge radius form the Lamb shift measurement.

- With the advance of variational numerical approach, various QED effects in helium atom have been obtained: nuclear recoil corrections, $m\,\alpha^6$ contribution to energy levels and $m\,\alpha^7$ to fine structure of 2^3P_J state. These allow for the improved tests of QED and more precise determination of physical constants

- Disproving the old superstition that photons cannot be localized. General arguments were given and specific examples exhibited which show that photons can be localized with exponential accuracy.

- It has been shown for the first time that the property of squeezing of the quantized electromagnetic field, widely discussed in quantum optics, has an intricate space-time structure.

- the adsorption on geometrically structured substrates has been analyzed within the effective Hamiltonian approach. The filling transition for an infinite wedge-like substrate as well as filling and wetting transitions on periodically corrugated substrates have been discussed. The possible shapes of non-volatile liquid drop located in a cone have been discussed as function of temperature. The adsorption of monolayers on crystal substrate has been described within the density functional approach.

PUBLICATIONS

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3. *Kinetics of ballistic annihilation and branching*, P.A.Rey, M.Droz, **J.Piasecki**, Phys. Rev. E **59**, 126 (1999)
4. *Influence of dissipation on stationary states*, Th.Biben, **J.Piasecki**, Phys.Rev.E **59**, 2192 (1999)
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6. *Lorentz's model with dissipative collisions*, Ph.A.Martin, **J.Piasecki**, Physica A **265**, 19 (1999)
7. *From the adiabatic piston to macroscopic motion induced by fluctuations*, **J.Piasecki**, Ch. Gruber, Physica A, **265**, 463 (1999)
8. *Stationary motion of the adiabatic piston*, Ch.Gruber, **J.Piasecki**, Physica A, **268**, 258 (1999).
9. *A model of non-equilibrium statistical mechanics*, **J.Piasecki**, Ya.G.Sinai, Proceedings of the Advanced Study Institute, Leiden, (1999)
10. *Image representation of a spherical particle near a hard wall*, **B. Cichocki** and R.B. Jones, Physica A 258, 273 (1998)
11. *Photoabsorption by an ion immersed in a plasma at any temperature*, K.Ishi-kawa, B.U. Felderhof, T.Blenski and **B. Cichocki**, J. Plasma Phys. **60**, 787 (1998)
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14. *Lubrication corrections for three-particle contribution to short-time self-diffusion coefficients in colloidal dispersions*, **B. Cichocki**, M.L.Ekiel-Jeżewska, and E. Wajnryb, J. Chem. Phys. 111, 3265 (1999)
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18. *Complete result for positronium energy levels at order* $m\,\alpha^6$, **K. Pachucki** and S. Karshenboim, Phys. Rev. Lett. **80**, 2101 (1998)
19. *Effective Hamiltonian approach to the bound state: energy of helium* n^3S_1 *-states in the order* $m\,\alpha^6$, **K. Pachucki**, J. Phys. B **31**, 2489 (1998)
20. *Quantum electrodynamics effects on singlet S-states of helium in the order* $m\,\alpha^6$, **K. Pachucki**, J. Phys. B. **31**, 3547 (1998)
21. *Quantum electrodynamics of weakly bound systems*, **K. Pachucki**, Hyperfine Interactions **114**, 55-70 (1998)

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23. *Simple derivation of helium Lamb shift*, **K. Pachucki**, J. Phys. B **31**, 5123-5133 (1998)
24. *Quantum electrodynamics effects on helium fine structure*, **K. Pachucki**, J. Phys. B 32, 137-152 (1999)
25. *Higher order recoil corrections to energy levels of two-body systems*, **K. Pachucki** and S.G. Karshenboim, Phys. Rev. A **60**, 2792-2798 (1999)
26. *Proton structure effects in muonic hydrogen*, **K. Pachucki**, Phys. Rev. A **60**, 3593-3597 (1999)
27. *Electron–Atom Collisions in a Laser Field*, F. Ehlotzky, **A. Jaroń**, **J. Z. Kamiński**, Phys. Rep. **297**, 63–154 (1998)
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29. *Intense field photo–electron emission, and high harmonic generation from crystal surfaces and quantum wells*, F. H. M. Faisal, **J. Z. Kamiński**, S. S. M. Soliman, Laser Phys. **8**, 129–135 (1998).
30. *Floquet–Bloch theory of photoeffect in intense laser fields*, F. H. M. Faisal, **J. Z. Kamiński**, Phys. Rev. A **58**, R19–22 (1998).
31. *Kroll–Watson low–frequency approximation revisited*, **A. Jaroń**, **J. Z. Kamiński**, Laser Phys. **9**, 81–87 (1999).
32. *Transitional effects in electron–atom scattering in a laser field near the interface between radiation filled space and vacuum*, **J. Z. Kamiński**, F. Ehlotzky, J. Phys. B**32**, 3193–3201 (1999).
33. *Asymmetries and dark angular windows in relativistic free-free transitions in a powerful laser field*, **J. Z. Kamiński**, F. Ehlotzky, Phys. Rev. A**59**, 2105–2110 (1999).
34. *Asymmetries in the angular distributions of above threshold ionization in an elliptically polarized laser field*, **A. Jaroń**, **J. Z. Kamiński**, F. Ehlotzky, Opt. Commun. **163**, 115–119 (1999).
35. *A selection rule in the theory of laser–assisted charged–particle scattering*, L. B. Madsen, **A. Jaroń**, **J. Z. Kamiński** and K. Taulbjerg, Phys. Rev. A **60**, 5126–5128 (1999).
36. *Angular and polarization effects in relativistic potential scattering of electrons in a powerful laser field*, **P. Panek**, **J. Z. Kamiński** i F. Ehlotzky, Can. J. Phys. **77**, 591–602 (1999).
37. *Quantum carpets made simple*, I.Marzoli, F.Saif, **I. Bialynicki-Birula**, O.M.Friesch, A.E. Kaplan, and W.P.Schleich, acta physica slovaca **48**, 323 (1998).
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43. *Born-Infeld nonlinear electrodynamics*, **I. Bialynicki-Birula**, Acta Physica Polonica B 30, 2875 (1999).
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45. *Fractional Talbot effect in phase space: A compact summation formula*, **K. Banaszek** ,**K. Wódkiewicz** and W. Schleich, Optics Express **2**, No.5, 169 (1998).
46. *Classical and Non Classical Interference*, **K. Wódkiewicz** and G. Herling Phys. Rev. A **57**, 815 (1998).
47. *Sampling quantum phase space with squeezed states*, **K. Banaszek** and **K. Wódkiewicz**, Optics Express **3**, No. 4, 141(1998).
48. *Squeezed Quantum Trigonometry*, P. Kochański and **K. Wódkiewicz**, in *Fifth International Conference on Squeezed States and Uncertainty Relations*, (NASA/CP-1998-206855 Reports), p. 109 (1998).
49. *Nonlocality of Einstein-Podolsky-Rosen State in Wigner representation*, **K. Banaszek** and **K. Wódkiewicz**, Phys. Rev. A **58**, 4345 (1998).
50. *Maximum-likelihood estimation of photon-number distribution from homodyne statistics*, **K. Banaszek**, Phys. Rev. A **57**, 5013 (1998).
51. *Testing Quantum Nonlocality in Phase Space*, **K. Banaszek** and **K. Wódkiewicz**, Phys. Rev. Lett. **82**, 2009 (1999).
52. *Direct measurement of the Wigner function by photon counting*, **K. Banaszek** , C. Radzewicz, **K. Wódkiewicz** and J. S. Krasiński, Phys. Rev. A **60**, 674 (1999).
53. *Nonlocality of the Einstein-Podolsky-Rosen state in the phase space*, **K. Banaszek** and **K. Wódkiewicz**, Acta. Phys. Slov. **49**, 491 (1999).
54. *Determination of the Wigner function from photon statistics*, **K. Banaszek** , C. Radzewicz, **K. Wódkiewicz** and J. S. Krasiński, Acta. Phys. Slov. **49**, 643 (1999).
55. *Operational Time of Arrival in Quantum Phase Space*, P. Kochański and **K. Wódkiewicz**, Phys. Rev. A **60**, 2689 (1999)
56. *Statistical uncertainty in quantum-optical photodetection measurements*, **K. Banaszek**, Journal of Modern Optics. **46**, 675 (1999)
57. *Quantum homodyne tomography with a priori constraints*, **K. Banaszek**, Phys. Rev. A **59**, 4797 (1999).
58. *Filling transition for a wedge*, **K.Rejmer**, S.Dietrich, and **M. Napiórkowski**, Phys. Rev. E **60**, 4027 (1999).

SCIENTIFIC DEGREES

D.SC.

- K.Pachucki, *Precise tests of quantum electrodynamics in hydrogen like atoms*, 1998

PH.D

- K. Banaszek, *Measuring quantum state in phase space* , 1999 (Supervisor K. Wódkiewicz)

M.SC.

- K. Krajewska, *Zero-range potential: an example of renormalization in nonrelativistic quantum mechanics*, 1999 (Supervisor J. Kamiński)
- T. Kryłowicz, *Functional methods in quantum mechanics: Feynman vs. Schwinger*, 1999 (Supervisor J. Kamiński)
- P. Nysiak, *Non-classical efects in parametric generation of light*, 1999 (Supervisor K. Wódkiewicz)
- L. Praxmeyer, *Classical and quantum interference in phase space*, 1999 (Supervisor K. Wódkiewicz)
- Grzegorz Kubalski *Adsorpcja na podłożu w kształcie stożka*, 1999 (Supervisor M. Napiórkowski)
- Łukasz Dębowski *Teoria funkcjonału gęstości dla monowarstw zaadsorbowanych na podłożu krystalicznym*, 1999 (Supervisor M. Napiórkowski)

GRANTS FOR RESEARCH PROJECTS

KBN GRANTS

1. B. Cichocki, *Dynamical scattering functions for interacting Brownian particles* , 1999-2001
2. M. Napiórkowski, *Surface phase trnasitions in nonstandard geometries* , 1997-1998
3. J. Piasecki, *Kinetic theory of conductivity, aggregation and annohilation*, 1997-1998
4. J. Piasecki, *Stationary states and scaling: effects of inelastic collisions*, 1999-2000
5. K. Pachucki, *Theoretical studies of two- and three-body problems in quantum electrodynamics*, 1996-1999
6. K. Wódkiwicz, *Operational trigonometry and quantum tomography of states of radiation field*, 1996-1998

7. K. Wódkiewicz, *Diagnostics of classical and quantum interference properties of electromagnetic radiation*, 1999-2000

8. J. Kamiński, *Theoretical investigations of nonlinear processes in the presence of laser fields*, 1997-2000

9. J. Kamiński, *Multiphoton processes in the presence of intense laser beams*, 1999-2000.

GRANT OF POLISH-GERMAN FOUNDATION

1. M. Napiórkowski, *Wetting of geometrically inhomogeneous substrate; singuarities in the related linear tension*, 1998-2000

9 DIVISION OF GENERAL RELATIVITY AND GRAVITATION

Head: Prof. Andrzej Trautman
Academic teachers: Prof. Marek Demiański, Prof. Wojciech Kopczyński, Dr hab. Jerzy Lewandowski, Dr. Paweł Nurowski, Dr hab. Jacek Tafel
Postgraduate students: 4

SCIENTIFIC ACTIVITIES

The scientific activity of the Division was concentrated around the following topics:

- Classical and quantum theory of gravitation,
- Cosmology and relativistic astrophysics,
- Spinors, twistors and self-dual equations.

SCIENTIFIC ACHIEVEMENTS

Czuchry and Kopczyński have shown how the multipole structure of extended bodies, described in the Kaluza-Klein theory, leads to a deviation of their motion from the one described by geodesics.

In 1998 Demiański completed work on a new edition in English of his major monograph on *Relativistic Astrophysics*; it is now in print at Cambridge University Press. In papers with Doroshkevich, he described the influence of the large scale perturbations of the gravitational potential on the spatial distribution of galaxies and on dark matter and determined the physical parameters of cosmic 'walls' and their interactions.

Many new results have been obtained by Lewandowski and his collaborators within the Ashtekar program of quantization of gravity. In particular, the volume operator has been regularized; the space of states, admitting the action of all constraint operators of gravitation, has been constructed; it was shown, that the existence of a Hilbert product contradicts the continuity of laps functions; the classical Poisson algebra of gravitational constraints has been compared with the corresponding operator algebra.

Tafel and Wójcik have found all one- and two-dimensional completely null algebras of conformal Killing vectors and applied these results to reduce the self-duality equations. Relativistic gravitational fields with close Newtonian analogs have been determined by Nurowski and Trautman in collaboration with Schucking of NYU. Nurowski has found a new formulation of Einstein's equations and shown how to associate an elliptic curve with every point of a conformally non-flat space-time. Together with Przanowski, he found the first example of a four-dimensional, Ricci-flat proper Riemannian manifold that is almost Kähler, but not Kähler. Trautman compared two definitions of spinor fields on Riemannian manifolds and formulated a conjecture on the relation between embeddability of CR spaces and the existence of pure electromagnetic waves. In a review article, written for the "Millenium" issue of *Classical and Quantum Gravity*, he surveyed work on gauge and optical aspects of gravitation.

PUBLICATIONS

1. *Multipole moments in Kaluza-Klein theories*, **E. Czuchry** and **W. Kopczyński**, Class. Quantum Grav. **15** (1998) 509.
2. *Gravitational potential perturbations and large scale bias*, **M. Demiański** and A. G. Doroshkevich, Proc. of the 8th Marcel Grossmann Meeting (Jerusalem, June 1997) ed. by T. Piran and R. Ruffini, World Scientific, Singapore 1998.
3. *The M-theory*, **M. Demiański**, in The McGraw-Hill 1999 Yearbook of Science and Technology, McGraw-Hill, New York 1998.
4. *Formation of super large scale structure and large scale bias*, **M. Demiański** and A. G. Doroshkevich,Astrophys. J. **512** (1999) 527.
5. *Statistical characteristics of formation and evolution of structure in the universe*, **M. Demiański** and A. G. Doroshkevich, Mon. Not. Roy. Astr. Soc. **283** (1999) 1281.
6. *Loop constraints: A habitat and their algebra*, **J. Lewandowski** and D. Marolf, Int. J. Mod. Phys. **D7** (1998) 299.
7. *On the consistency of the constraint algebra in spin network quantum gravity*, **J. Lewandowski**, R. Gambini, D. Marolf and J. Pullin, Int. J. Mod. Phys. **D7** (1998) 97.
8. *Quantum Theory of Geometry II: Volume operators*, **J. Lewandowski** and A. Ashtekar, Advances in Theoretical and Mathematical Physics, inaugural volume: issue 2 (1998)
9. *Diffeomorphism invariant quantum field theories of connections in terms of webs*, **J. Lewandowski** and T. Thiemann, Class. Quantum Grav. **16** (1999) 2299.
10. *Degenerate sectors of the Ashtekar gravity*, **J. Lewandowski** and J. Wiśniewski, Class. Quantum Grav. **16** (1999) 3057.
11. *Elliptic fibrations associated with the Einstein space-times*, **P. Nurowski**, J. Math. Phys. **39** (1998) 5481.
12. *On a certain formulation of the Einstein equations*, **P. Nurowski** , J. Math. Phys. **39** (1998) 5477.
13. *Extensions of bundles of null directions*, **P. Nurowski** , L. Hughston and D. Robinson, Class. Quantum Grav. **16** (1999) 255.
14. *A four-dimensional example of a Ricci flat metric admitting almost-Kähler non-Kähler structure*, **P. Nurowski** and M. Przanowski, Class. Quantum Grav. **16** (1999) L9.
15. *Relativistic gravitational fields with close Newtonian analogs*, **P. Nurowski** , E. Schucking and **A. Trautman**, Ch. 23 in On Einstein's Path, ed. by A. Harvey, Springer-Verlag, New York 1999.
16. *Null Killing vectors and reductions of the self-duality equations*, **J.Tafel** and **D.Wójcik**, Nonlinearity **11** (1198) 835.
17. *Reflections and spinors on manifolds*, **A. Trautman**, in CP453 Fields, Particles and Gravitation, ed. by J. Rembieliński, American Institute of Physics, 1998.
18. *On complex structures in physics*, **A. Trautman**, Ch. 34 in On Einstein's Path, ed. by A. Harvey, Springer-Verlag, New York 1999.
19. *Gauge and optical aspects of gravitation*, **A. Trautman**, Class. Quantum Grav. **16** (1999) A157.

WORKSHOPS AND CONFERENCES

- The Infeld Centennial Meeting, Warsaw, June 22–23 ,1998

SCIENTIFIC DEGREES

M.SC.

- Marcin Bobieński *Twistorial construction of harmonic maps and its analogs in pseudoeuclidean signatures* (supervisor: dr Paweł Nurowski)
- Jacek Daniel Litwin *Gravitational waves in the open Universe* (supervisor: prof. Marek Demiański)
- Mariusz Mroczek *Twistor methods and spacetime* (supervisor: dr hab. Jerzy Lewandowski)
- Andrzej Okołów *New selfdual variables in canonical gravity* (supervisor: dr hab. Jerzy Lewandowski)
- Adam Szereszewski *Symmetry reduction of the Einstein equations* (supervisor: prof. Jacek Tafel)
- Monika Szymkowiak *Nucleosynthesis of light elements in the early Universe* (supervisor: prof. Marek Demiański)

GRANTS FOR RESEARCH PROJECTS

KBN GRANTS

- Evolution of inhomogeneities in the open cosmological models and their observational consequences, 1997–1998, (M. Demiański)
- Mechanisms of formation and evolution of density perturbation and gravitational waves in open cosmological models, 1998-2001, (M. Demiański, J. Litwin)
- Geometrical methods of classical field theory and of quantum theory of gravity, 1996–1998 (S. Bażański, W. Kopczyński, J. Lewandowski, P. Nurowski, J. Tafel, A. Trautman)
- Classical and quantum theory of gravity and their geometrical methods, 1999–2002 (S. Bażański, W. Kopczyński, J. Lewandowski, P. Nurowski, J. Tafel, A. Trautman)

10 DIVISION OF MATHEMATICAL PHYSICS

Head: Prof. Stanisław Bażański
Academic Teachers: Dr. Adam Doliwa, Prof. Bohdan Mielnik [1], Prof. Antoni Sym
Postgraduate Students: 5

SCIENTIFIC ACTIVITIES

The scientific activities concentrate on the following subjects of research:

- The principles and structure of quantum mechanics, the control of quantum states by the use of external, variable fields.
- The classification and study of integrable geometries by means of spectral soliton methods.
- Discrete integrable geometries vs. discrete soliton systems.
- Various dynamical problems in the theory of relativity.
- An analysis of diverse relations between geometric properties of relativistic space times and corresponding physical effects.

SCIENTIFIC ACHIEVEMENTS

- To the classical counterpart of the Schrödinger equation the algorithm of angular variables introduced in 1926 by Prüfer was developed.. This algorithm has now been supplemented by a procedure which enables one to describe the discrete spectrum with the help of a bifurcation into two simultaneous classical motions: the rotation and compression. This description is independent of the traditional perturbation methods. It has been shown that the energy eigenvalues reduce themselves to the parameters which characterize the bifurcation of classical orbits. The formalism introduced in this work was applied to potential wells of various types.
- The problem of the falsifiability of the geodesic hypothesis in the general theory of relativity was examined. In the classical, geometric approach to the problem of motion, it is not a uniquely defined issue of how to recognize the meaning that should be ascribed to an experimental verification of the fact that a world line of a test body in a given gravitational field is a geodesic line in the space time which corresponds to the field. Is such a verification a confirmation of a definite property of the motion or is it rather a confirmation of a proper choice of the gravitational field represented by the metric tensor of the space time under consideration. In other words, in case an observed world line of a celestial body were not a geodesic line with respect to an assumed gravitational field, perhaps the geodesicity of the world line could be

[1] joint appointment: *parallel position*: Profesor Titulo, Departamento de Fisica, CINVESTAV, A.P 14-740, 07000 México, D.F.

enforced by an appropriate modification of the field. This non-uniqueness seems to indicate that the geodesic hypothesis, as well as other statements about the properties of the motion of bodies in a field, is not falsifiable in the meaning introduced by Karl Popper. It has been, however, shown by S. Bażański that from the theorems about the synchronization of clocks, shown in his previous works, it follows that the geodesic hypothesis is definitely falsifiable. Its falsification could be performed by observing on boards of a family of satellites the indication of clocks which previously were synchronized by an exchange of light signals. Only if the world lines of the satellites are geodesics, the synchronization and the so-called synchronization gap will be preserved in time. It thus means that the geodesic hypothesis may be verified without any appeal to the notion of the space time metric.

- A geometric formalism has been introduced of how to describe in a relativistic way effects in which a split of light rays occurs which is next followed by their reconvergence and refocussing, after the rays have passed different optical paths. General formulas have been derived for the difference of the arrival times of the rays to an observer, for their frequency shifts, and corresponding phase differences. The formalism derived can equally well be applied within the frameworks of both the special and the general theory of relativity. Nor does the formalism depend on the mechanism that caused the split, which can be a result of an optical device or of the light bending and focussing properties of the gravitational field itself.

- All the papers by A. Doliwa (and his coworkers) cover a rather new subject of the soliton theory: "discrete integrable geometries". The underlying idea is as follows: to lift the well known connections between classical differential geometry and integrable systems onto the level of a discrete geometry (and discrete integrable systems as well). The idea turns out to be very fruitful. In particular, almost forgotten branches of the classical differential geometry (e.g. the theory of conjugated nets) reveal their unexpected “integrable” aspects which survive after “discretization”. One can thus expect that some fundamental (and geometric) unifying theory of integrable (soliton) systems will be constructed in a near future.

- The two papers [5] and [6] concern a geometric interpretation of the so called Bäcklund transformations of the soliton theory. It turns out that these transformations can be interpreted as maps between focal surfaces of rectilinear congruences (2 - parameter families of straight lines in E^3). A thesis of the existence of “old soliton theory” is put forward and illustrated by various examples.

PUBLICATIONS

1. *The Split and Propagation of Light Rays in Relativity*, **Stanisław L. Bażański**, On Einstein's Path, ed. Alex Harvey, Springer-Verlag, New York, 1998
2. *$\bar{\partial}$–Reductions of the Multidimensional Quadrilateral Lattice: the Multidimensional Circular Lattice*, **A. Doliwa**, S. V. Manakov & P. M. Santini, Comm. Math. Phys. **196** (1998) 1–18.
3. *Charged Free Fermions, Vertex Operators and Transformation Theory of Conjugate Nets*, **A. Doliwa**, M. Mañas, L. Martínez Alonso, E. Medina & P. M. Santini, J. Phys. A **32** (1999) 1197–1216.
4. *Quadratic Reductions of Quadrilateral Lattices*, **A. Doliwa**, J. Geom. Phys. **30** (1999) 169–186.
5. *Rectilinear congruences and Bäcklund transformations*, **R. Prus** & **A. Sym**, in "Nonlinearity and Geometry", PWN (Polish Scientific Publishers) 1998
6. *Weingarten congruences and non-auto-Bäcklund transformations for hyperbolic surfaces*, **M. Nieszporski** & **A. Sym**, in "Nonlinearity and Geometry", PWN (Polish Scientific Publishers) 1998
7. *Bäcklund transformations for hyperbolic surfaces in E^3 via Weingarten congruences*, **M. Nieszporski** & **A. Sym**, Teoreticheskaya i Matematicheskaya Fizika, vol. 122, no 1, pp. 102–117, 1999.
8. *Magnetic Control of Sqeezing Effects*, F. Delgado C. and **B. Mielnik**, J.Phys. A**31**, 309 (1998).
9. *Sqeezed States and Helmholtz Spectra*, F. Delgado C., **B. Mielnik** and M.A. Reyes, Phys. Lett. A**237**, 359 (1998).
10. *A simple generation of exactly solvable anharmonic oscillators*, D.J. Fernandez C., V. Hussin and **B. Mielnik**, Phys. Lett. A**244**, 1 (1998).
11. *Are there Floquet quanta?*, F. Delgado C. and **B. Mielnik**, Phys. Lett. A**249**, 369 (1998).
12. *Floquet quanta: an unfinished story...*, **B. Mielnik** and F. Delgado C. in Symmetries in Quantum Mechanics and Quantum Optics, eds. A. Ballestros et al., Burgos, Spain (1999).
13. *Some properties of light propagation in relativity*, **Stanisław L. Bażański**, in "Particles Fields and Gravitation", p.421, ed. J. Rembieliński, AIP Conference Proceedings, American Institute of Physics, Woodbury, N.Y., 1998.
14. *Geometric approach to the split and propagation of light rays* , **Stanisław L. Bażański**, in "The Eihgt Marcel Grossmann Meeting", part A, p.398, eds T. Piran, R. Ruffini, World Scientific, Singapore, 1999.

GRANTS FOR RESEARCH PROJECTS

KBN GRANTS

1. Completely (soliton) systems and geometry of submanifolds (1995-1998)

11 DIVISION OF NUCLEAR STRUCTURE THEORY

Head: Prof. Jacek Dobaczewski
Academic teachers: Prof. Witold Nazarewicz[2] Prof. Stanisław G. Rohoziński, Dr hab. Wojciech Satuła, Prof. Zdzisław Szymański[3], Dr hab. Tomasz Werner
Postgraduate students: 3

OBITUARY

In 1999 we lost our teacher, friend, and collaborator. On September 5, 1999 Professor Zdzisław Szymański, the founder of nuclear structure theory in Poland, passed away during the Nuclear Physics Summer School in Krzyże. He was actively doing research till his very last days. We shall always remember him.

Members of the Division

SCIENTIFIC ACTIVITIES

Scientific activities are focused on investigating the following main research subjects:

- Effective nucleon-nucleon interactions.
- Nuclei with large neutron or proton excess.
- Superheavy nuclei.
- Nuclei with large deformations, super- and hyperdeformation.
- Fast nuclear rotation.
- Quadrupole collective states.
- Collective vs. single-particle motion, dissipative phenomena.

SCIENTIFIC ACHIEVEMENTS

In 1998 and 1999, five members of the Division have published 30 papers in refereed periodicals (see the list below), and have presented 31 invited talks and 14 contributions at international conferences. During this period of time the following main research projects have been realized:

[2] on leave of absence
[3] deceased September 5, 1999

- *Superdeformed states*
  Hartree-Fock calculations for the excited well-deformed rotational band in ^{58}Cu has been presented in Ref. [5]. The first excited state in this band decays via γ emission to the spherical states associated with the first minimum in the potential, thus providing for its unambiguous assignment to ^{58}Cu. In contrast, its bandhead decays via emission of a prompt 2.4(1) MeV proton to an excited state in the daughter nucleus ^{57}Ni. This has been the first observation of proton decay from states associated with a deformed secondary minimum in the potential. Self-consistent Hartree-Fock calculations reproduce well both the large collectivity of this band and the general trend of its moment of inertia. In Ref. [15], the nuclear structure of the doubly magic nucleus ^{56}Ni has been investigated at high spins within the Hartree-Fock method. Configurations of two well-deformed rotational bands have been identified and compared with experimental data. Similar theoretical methods have also been used in Ref. [19] to describe the yrast superdeformed band in ^{61}Zn. Comparison of the $J^{(2)}$ dynamical moments of inertia of this band with those in ^{60}Zn shows a nearly complete blocking of the observed alignment in ^{60}Zn, indicating that T=0 proton-neutron pair correlations may be present in ^{60}Zn. The superdeformed (SD) bands in Hg-Pb nuclei of mass $A\sim$190 are unique in many respects. Characteristic rise of their dynamical moments of inertia (MoI) versus rotational frequency clearly indicates importance of pairing correlations in these bands, unlike in SD bands in lighter nuclei. Stability of these highly elongated shapes against rotational distortion offers a unique test ground to study very subtle aspects of nuclear superconductivity. Ref. [22] attempts at a systematic study of the MoI in these bands in a framework of mean-field model. Both Strutinsky-type as well as fully self-consistent Hartree-Fock-Bogolyubov calculations have been presented. It has been shown that the calculations reproduce general experimental properties very well. They do encounter problems, however, in reproducing specific alignments of the SD bands or the identical bands.

- *Properties of weakly bound systems*
  In Ref. [6] shell corrections in the finite one-body, spherically symmetric potentials have been analyzed. A new method has been employed, which allows for a description of shell corrections in exotic nuclei where continuum effects have to be taken into account. The method is based on solving the Schrödinger equation on complex energy plane. The results have been compared with those of the Wigner-Kirkwood expansion, and the asymptotic properties of solutions have been investigated in detail.
  Continuum effects in the weakly bound nuclei close to the drip-line have been in Ref. [16] investigated using the analytically soluble Pöschl-Teller-Ginocchio potential. Pairing correlations have been studied within the Hartree-Fock-Bogolyubov method. We have shown that both resonant and non-resonant continuum phase space is active in creating the pairing field. The influence of positive-energy phase space has been quantified in terms of localizations of states within the nuclear volume.

Beta-decay rates for spherical neutron-rich r-process waiting-point nuclei have been calculated in Ref. [17] within a fully self-consistent Quasiparticle Random-Phase Approximation, formulated in the Hartree-Fock-Bogolyubov canonical single-particle basis. The same Skyrme force has been used everywhere in the calculation, except in the proton-neutron particle-particle channel, where a finite-range force has been employed. In all but the heaviest nuclei, the resulting half-lives are usually shorter by factors of 2 to 5 than those of calculations that ignore the proton-neutron particle-particle interaction. The shorter half-lives alter predictions for the abundance distribution of r-process elements and for the time it takes to synthesize them.

- *Pairing correlations in nuclei*
  The odd-even staggering (OES) of binding energies is a universal property of finite fermion (mesoscopic) systems. The underlying mechanism beyond OES is, however, system dependent. For example, in metallic clusters, it is predominantly due to the underlying non-spherical mean field, while in ultrasmall metallic grains OES is mainly related to the blocking mechanism of superconducting correlations by an unpaired electron. In atomic nuclei, additional complications arise because of the symmetry energy caused by a simultaneous presence of two types of fermions. In Ref. [7] we have investigated the nuclear OES, and concluded that, in light nuclei, it has two competing components, one related to pairing and the other one to deformed mean field.

- *Shape-coexistence phenomena*
  The phenomenon of shape coexistence has been discussed in Ref. [18] within the self-consistent Hartree-Fock method and the nuclear shell model. The occurrence of the coexisting configurations with different intrinsic shapes has been traced back to the properties of the effective Hamiltonian. The nucleus ^{32}Mg has been found to be a classic example of shape coexistence; the spherical and deformed configurations are close in energy and shape mixing is expected. For most Skyrme parameterizations used, the N=28 gap is predicted to be rather small. This gives rise to strong deformation effects around ^{44}S. The strong coexistence effects are also predicted for ^{80}Zr and ^{98}Zr. Both families of models applied in this work, i.e., the self-consistent mean-field models and the shell model, should be viewed as effective theories. That is, their predictive power crucially depends on the effective interaction assumed.

- *Super-heavy nuclei* Structure of the odd-N superheavy elements with $Z<120$ and $N<175$ has been investigated in Ref. [21] using the self-consistent Skyrme-Hartree-Fock-Bogolyubov method with pairing. This is the first self-consistent analysis of one-quasiparticle states in this mass region. Microscopic analysis of α-decay energies and deformations has been performed. Good agreement was obtained with the recently reported α-decay chains of $^{289}114$ and $^{293}118$. The ground states of the N=175 isotones were calculated to be the high-Ω isomeric states based on the [707]15/2$^-$ orbital. Because of structural arguments, this state is probably bypassed

by the α-decays. (The same is true for the high-Ω ground states at N=171.) This result may explain the observed lower cross section for the production of ^{293}118 ($\sim$2 pb) as compared to calculations by Smolańczuk ($\sim$670 pb).

- *Proton emitters*
  Proton radioactivity is an excellent example of the elementary three-dimensional quantum-mechanical tunneling. Lifetimes of proton emitters provide a very direct information on the wave functions of the narrow proton resonances, and the energies of emitted protons tell us about the topology of the nuclear binding energy surface in the vicinity of the proton drip-line. In Refs. [28,29] experimental data on proton-emitting states in ^{141}Ho have been analyzed using the coupled-channel Schrödinger equation with outgoing boundary conditions. The observed resonances have been interpreted in terms of the [411]1/2$^+$ and [523]7/2$^-$ single-proton orbitals. It has been concluded, that the decay process of a Nilsson orbital is governed by the lowest-ℓ partial wave allowed by the angular momentum and parity conservation

- *Collective quadrupole excitations*
  The low-lying collective states in nuclei have usually been interpreted as the quadrupole excitations. It has been known for a long time that inertial functions for such excitations when calculated microscopically are too small and do not describe the collective energy levels correctly. To improve a description of collective states it has been proposed to couple the quadrupole excitations to the pairing vibrations. The effect of zero-point pairing vibrations on the quadrupole excitations gives a very good description of collective states in Ru and Pd isotopes [26,27] and improves essentially the description for the $50 < Z,\ N < 82$ nuclei [25].

- *Polarizational correlations of the γ radiation emitted from oriented nuclei*
  Investigation of the direction–polarization and polarization–polarization correlations of γ quanta emitted from the oriented nucleus is a powerful method which can lead to the unique assignment of spins and parities of nuclear states. A necessary formulae for double correlations have been derived and applied to determination or confirmation of spins and parities of nuclei produced in heavy-ion reactions [23,24].

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SCIENTIFIC DEGREES

D.SC.

- Wojciech Satuła, *Nuclear superconductivity*, 1999.

M.SC.

- Andrzej Godlewski, *Mass and charge radii of atomic nuclei*, (Supervisor: Tomasz Werner),1999.
- Mariusz Dębowski, *Coupling of pairs of particles with the core in odd-odd nuclei*, (Supervisor: Stanisław G. Rohoziński), 1999.
- Jolanta Karny, *Rotational bands in superdeformed nuclei in the rare-earth region*, (Supervisor: Jacek Dobaczewski), 1999.

GRANTS FOR RESEARCH PROJECTS

KBN GRANTS

1. Study of effective nuclear interactions via application of nuclear models and methods to the description of nuclear phenomena (1998–2000)
2. Analysis of low-lying collective states of atomic nuclei (1997–1999)

GRANTS OF THE POLISH-FRENCH COOPERATION POLONIUM:

1. Atomic nuclei and their symmetries (1998-1999)

12 DIVISION OF THEORY OF ELEMENTARY PARTICLES AND INTERACTIONS

Head: Prof. Stefan Pokorski
Academic teachers: Dr. Zygmunt Ajduk, Dr hab. Jan Bartelski, Dr hab. Piotr Chankowski, Dr hab. Bohdan Grządkowski, Prof. Jan Kalinowski, Dr hab. Maria Krawczyk, Prof. Wojciech Królikowski, Dr hab. Zygmunt Lalak, Dr hab. Krzysztof Meissner, Dr. Mikołaj Misiak, Dr hab. Marek Olechowski, Dr hab. Jacek Pawełczyk, Dr. Maciej Pindor, Dr. Janusz Rosiek, Dr. Michał Spaliński[4]
Postgraduate students: 8

SCIENTIFIC ACTIVITIES

A broad spectrum of interests is represented, ranging from phenomenological studies within the scope of the Standard Model to formal aspects of string theory. Special emphasis is given to supersymmetric extensions of the Standard Model, unification scenarios, string theory, supergravity, and the problem of fermion mass generations. The other topics include the structure of hadrons and photons, and substructure of quarks and leptons. Some members of our group are also actively involved in cosmological research.

SCIENTIFIC ACHIEVEMENTS

The research conducted in the Division for Theory of Particles and Elementary Interactions during the two year period 1998 - 1999 has been mainly focussed on physics beyond the Standard Model. The major part of altogether 98 publications is devoted to various aspects of supersymmetric and superstring theories.

Minimal supersymmetric extension of the Standard Model (MSSM) provides a well defined theoretical framework for studying low energy effective supersymmetry as a (still hypothetical) fundamental symmetry of Nature. Investigations of the MSSM are of crucial importance for predicting phenomenological consequences of supersymmetry and for experimental search for it. One should stress that experimental search for supersymmetry is the main goal for future accelerators.

A number of very important papers has been published by the members of our Division which provide a very systematic study of the phenomenological aspects of the low energy supersymmetry. The papers by Chankowski et al. give the complete picture of the potential supersymmetric effects on the precision electroweak observables and, vice versa, of the impact of the present experimental data on our ideas about low energy supersymmetry. In particular, several ideas on the possibility of the existence of relatively light superparticles have been pioneered by our group. The papers by Misiak et al. concentrate on rare processes (mainly the flavour changing neutral current processes). Very important results consist of the next-to-leading QCD corrections to some of those processes (e.g. $b \to s\gamma$) and of a systematic study of such processes in the MSSM. Potential new sources of CP violation in the MSSM have been studied by Pokorski et al. Both groups of papers

[4]till September 1998

belong now to classic literature on the subject and the summary of the results has also been published as contributions to some books.

A crucial issue for physics beyond the Standard Model is the existence of a Higgs boson(s) and its (their) properties. A number of papers has been published on the properties of the Higgs sector in the Standard Model and beyond (Chankowski et al., Kalinowski et al., Krawczyk et al.). The results have theoretical value (relation to the naturalness problem) and are also important for experimental groups. Several ideas have been pioneered by our group (e.g. the large tg β scenario in the MSSM and the search for the Higgs boson in bremstrahlung-like processes).

In the last years experiments at LEP (CERN) and HERA (DESY) showed some exciting signatures which may be a signal of new physics (although statistical fluctuations are not yet excluded). Kalinowski et al. devoted a number of papers to reviewing new physics which might be consistent with those signals. The MSSM with non-conserved R-parity emerged as the most serious candidate.

The main virtue of supersymmetry is that it provides a well defined theoretical framework for extrapolating low energy physics up to the Grand Unified (GUT) or even Planck scale. We have been extensively investigating this link both from the phenomenological and more theoretical sides. On the phenomenological level a bottom-up approach has been proposed to the physics at those large scales. In this approach one tries to make maximal use of the available data to learn about large scale physics. In the papers by Chankowski et al. and Olechowski et al. the bottom-up approach is used to obtain constraints on the pattern of soft supersymmetry breaking and on the Yukawa coupling.

Very important papers by Lalak et al. and Olechowski et al. have been published on the origin of supersymmetry breaking in supergravity theories and in the M-theory, which is considered now as a serious candidate for the fundamental theory of elementary interactions (including gravity). These papers belong to a few most pioneering articles on the subject. Various aspects of string theory have been investigated by Meissner, Pawełczyk, Spaliński et al.

Particle physics, and particularly physics at the Planck scale, is strongly linked to cosmological and astrophysical questions. Physics beyond the Standard Model so intensively investigated by our group cannot avoid this link. Lalak et al., Olechowski et al., Meissner et al. devoted important part of their research to study the interface of particle physics and cosmology. Among the most important results one should mention the results on the supersymmetric candidates for dark matter (Olechowski), on inflationary scenarios in supergravity models (Lalak), on string cosmology and the pre-Big-Bang era (Meissner).

Supersymmetry, although the dominant subject of research in our group, was not the only one. Important investigations have been conducted in the field of neutrino physics. Neutrino masses and oscillations have been studied in the papers by Królikowski and by Chankowski et al. Search for new physics in the top quark and Higgs sector is the subject of several interesting papers by Grządkowski et al. In particular the possibility of the CP violating effects in those sectors has been thoroughly investigated.

The research topics of our group include also the "hotąspects of strong interaction physics. Bartelski et al. have several interesting results on the polarized nucleon structure

functions. The important issue of the photon structure functions has been discussed in a number of papers by Krawczyk et al. This subject is topical due to the new generation of deep inelastic experiments at HERA (DESY).

Finally, some interesting results on applications of Padé approximants in physics were obtained by Pindor *et al.*

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43. *Supergravity and Supersymmetry Breaking in Four-Dimensions and Five-Dimensions*, **Z. Lalak**, **S. Pokorski**, J. Ellis, S. Thomas, Nucl. Physics **B563**, 107-124 (1999)

44. *Beyond the Standard Embedding in M Theory on S1/Z(2)*, **Z. Lalak**, **S. Pokorski**, S. Thomas, Nuclear Physics **B549**, 63-97 (1999)

45. *String Dualities in the Presence of Anomalous U(1) Symmetries*, **Z. Lalak**, S. Lavignac, H. P. Nilles, Nucl. Phys. **B559**, 48-70 (1999)

46. *Five-Dimensional Aspects of M Theory Dynamics and Supersymmetry Breaking*, **Z. Lalak**, **S. Pokorski**, J. Ellis, W. Pokorski, Nuclear Physics **B540**, 149-186 (1999)

47. *Classical Inhomogeneities in String Cosmology*, **K. A. Meissner**, A. Buonanno, C. Ungarelli, G. Veneziano, Phys. Rev. **D57**, 2543-2556 (1998)

48. *Quantum Inhomogeneities in String Cosmology*, **K. A. Meissner**, A. Buonanno, C. Ungarelli, G. Veneziano, J. High Energy Phys. **01**, 004 (1998)

49. *Supersymmetry Breakdown at Distant Branes: the Super Higgs Mechanism*, **K. Meissner**, **M. Olechowski**, H. P. Nilles, Nucl. Physics **B561**, 30-42 (1999)

50. *Supersymmetry and FCNC Effects*, **M. Misiak**, **S. Pokorski**, **J. Rosiek**, in Heavy Flavors II, eds. A. J. Buras and M. Lindner, Advanced Series on Directions in High Energy Physics, World Scientific, Singapore (1998)

51. *$|\Delta F| = 1$ Nonleptonic Effective Hamiltonian in a Simpler Scheme*, **M. Misiak**, K. Chetyrkin, M. Münz, Nuclear Physics **B520**, 279 (1998)

52. *Beta Functions and Anomalous Dimensions up to Three Loops*, **M. Misiak**, K. Chetyrkin, M. Münz, Nuclear Physics **B518**, 473-494 (1998)

53. *QCD Corrections to FCNC Decays Mediated by Z Penguins and W Boxes*, **M. Misiak**, J. Urban, Physics Letters **451**, 161-169 (1999)

54. *Supersymmetry Breakdown at a Hidden Wall*, **M. Olechowski**, H. P. Nilles, M. Yamaguchi, Nuclear Physics **B530**, 43 - 72 (1998)

55. *Relic Abundance of Neutralinos in Heterotic String Theory: Weak Coupling vs. Strong Coupling*, **M. Olechowski**, Y. Kawamura, H. P. Nilles, M. Yamaguchi, J. High Energy Phys. **6**, 8 (1998)
56. *AdS5xS5 Black Hole Metric at* $O(\alpha'^3)$, **J. Pawełczyk**, S. Theisen, J. High Energy Phys. **10**, 9809 (1998)
57. *On Higher Order* α' *Corrections to Black Brane Geometries*, **J. Pawełczyk**, S. Theisen, in Proceedings of the 2nd Conference on Quantum Aspects of Gauge Theories, Supersymmetry and Unification, Corfu 1998 , p. 382 - 387, Springer (1999)
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59. *Pade-type Approximants and Errors of Pade Approximants*, **M. Pindor**, J. Gilewicz, Journal of Comp. and Appl. Math., **99**, 1 (1998)
60. *Pade Approximants and Noise: Rational Functions*, **M. Pindor**, J. Gilewicz, J. of Comp. and Applied Math., **105**, 285 - 297 (1999)
61. *Determining the Relative Size of the CP Even and CP Odd Higgs Boson Couplings to a Fermion at the LHC*, **J. Pliszka**, J. F. Gunion, Physics Letters **B444**, 136 - 141 (1998)
62. *What Do We Learn about Supersymmetry from Not Having Discovered It Yet?*, **S. Pokorski**, in Proc. of Int. Workshop on Physics Beyond the Standard Model: from Theory to Experiment, Valencia 1997, World Scientific, 107 - 116 (1998)
63. *Photon Signatures for Low-Energy Supersymmetry Breaking and Broken R Parity*, **S. Pokorski**, M. Carena, C.E.M. Wagner, Physics Letters, **B430**, 281 (1998)
64. *Stabilized Singlets in Supergravity as a Source of the* μ*-Parameter*, **S. Pokorski**, C. Kolda, N. Polonsky, Physical Review Letters **80**, 5263 (1998)
65. *Status of Low Energy Supersymmetry*, **S. Pokorski**, Acta Physica Polonica **B30**, 1759 - 1773 (1999)
66. *What Are We Learning about Supersymmetry from Not Having Discovered It Yet?*, **S. Pokorski**, in Proc. of Workshop on Phenomenological Aspects of Superstring Theories (PAST-97), Trieste 1997, World Scientific, 211 - 219 (1999)
67. *Supersymmetric CP Problem without Flavour Violation*, **J. Rosiek**, Acta Physica Polonica **B 30**, 3379-3400, (1999)
68. *Large N Superconformal Gauge Theories and Supergravity Orientifolds*, **M. Spaliński**, A. Fayyazuddin, Nuclear Physics **B535**, 219-232 (1998)

SCIENTIFIC DEGREES

D.SC.:

- Piotr Chankowski, *Precision Tests of the Minimal Supersymmetric Extension of the Standard Model*
- Zygmunt Lalak, *Supersymmetry Breaking and Cosmology of Light Scalar Fields in Supergravity Models Inspired by String Theory*
- Jacek Pawełczyk *Topological Terms in String Theory*

M.SC.:

- Konrad Baranowski, *Poprawki elektrodynamiki kwantowej do rozpadu $b \to s\gamma$ (The QED corrections to decay $b \to s\gamma$)*, (Supervisor: Mikołaj Misiak)
- Rafał Ciesielski, *Naruszenie supersymetrii w supergrawitacji sprzężonej z materią (Supersymmetry violating in supergravitation coupled to the matter)*, (Supervisor: Zygmunt Lalak)
- Marcin Flak, *Modele czasoprzestrzeni w wielowymiarowych kwantowych teoriach pola (Models of time-space in multidimensional quantum field theories)*, (Supervisor: Krzysztof Meissner)
- Piotr Grzywacz, *Kosmologiczna inflacja w modelach supergrawitacyjnych (The cosmological inflation in models of supergravity)*, (Supervisor: Zygmunt Lalak)
- Jerzy Holona, *Efektywne sprzężenia Yukawy w Minimalnym Supersymetrycznym Modelu Standardowym (The effective Yukawa coupling in the minimal supersymmetric standard model)*, (Supervisor: Janusz Rosiek)
- Adam Jakóbek, *Neutralne prądy zmieniające zapach w modelach z niskoenergetycznym łamaniem supersymetrii (The charm changing neutral currents in models with a low-energy supersymmetry breaking)*, (Supervisor: Piotr Chankowski)
- Paweł Jankowski, *Fotoprodukcja kwarków $b\bar{b}$ oraz mezonów B (Photoproduction of quarks $b\bar{b}$ and mesons B)*, (Supervisor: Maria Krawczyk)
- Urszula Jezuita-Dąbrowska, *The Polarization States of the Virtual Photon in $ep \to e\gamma X$ at the HERA Collider* (Supervisor: Maria Krawczyk)

GRANTS FOR RESEARCH PROJECTS

KBN GRANTS

1. Phenomenological Analysis of Proton and Photon Structure in view of Current and Future Experiments ... (1996 - 1999)
2. Studies on Phenomenological Aspects of Supersymmetric Theories (1997 - 1998)
3. Search for Signatures of New Physics in Accelerators of Present and Future Generations ... (1997 - 1999)
4. Studies on Electroweak Interactions of Higgs Particles and Heavy Quarks (1998-2000)
5. Unification of Fundamental Interactions in Supergravity, String Theory and M-Theory (1998 - 2000)
6. Studies on Interactions from Planck Scale to Electroweak Scale (1999 - 2000)

PROJECTS OF THE US-POLAND MARIA SKŁODOWSKA-CURIE JOINT FUND II:

1. Topics in Supersymmetry (1996 - 1999)
2. CP Violation in Physics of Higgs Particles and Heavy Quarks (1996 - 1999)
3. High Energy Physics, Particle Cosmology and Large Scale Structures (1996 - 2000)

GRANTS OF THE POLISH-GERMAN COOPERATION FOUNDATION:

1. Polish-German Cooperation in Physics of Elementary Particles (1998)
2. Theoretical Research on Fundamental Interactions (1998-2001)

GRANTS OF THE POLISH-FRENCH COOPERATION POLONIUM:

1. Supergravity and Particle Physics (1998 - 1999)
2. Models of Fundamental Interactions in String M Theory and Their Applications in Cosmology (1998 - 1999)
3. Rational Interpolation in Presence of Noise (1998 - 1999)

MOBILITY JOINT EUROPEAN PROJECT OF THE TEMPUS:

1. Courses and Projects for Students in Pure and Applied Physics (1995 - 1998)

WORKSHOPS AND CONFERENCES

- International Workshop on Photon-Photon and Photon-Proton Processes, Warsaw, June 12 - 14, 1998
- First European Meeting "From Planck Scale to Electroweak Scale", Kazimierz, May 24 - 30, 1998
- Educational TEMPUS Workshop on Supersymmetry, Warsaw, May 22 - 23, 1998

13 DIVISION OF THEORY OF HADRONS AND LEPTONS

Head: Prof. Józef Namysłowski
Academic teachers: Dr hab. Aleksy Bartnik, Dr hab. Stanisław Głazek, Dr. Jacek Jasiak, Dr. Piotr Rączka, Prof. Andrzej Szymacha[5], Prof. Józef Werle[6]
Postgraduate students: 4

SCIENTIFIC ACTIVITIES

The scientific activity of the Division was concentrated on the following topics:

- Theory of effective interactions of quarks and gluons.
- Singularities of multipoint Green functions in model quantum field theories.
- Renormalization group procedure for hamiltonians in quantum field theory and its application in particle physics.
- Variational estimates of hadron bound states in quantum chromodynamics in hamiltonian approach.
- Resummation and optimization of higher order perturbative predictions in quantum chromodynamics.

SCIENTIFIC ACHIEVEMENTS

- Namysłowski and Radożycki found a way to simplify significantly the Dyson-Schwinger equations for the $1+1$ Schwinger model. As a consequence they obtained analytic results for higher order Green functions, including analytic solutions for the four point Green functions, both in the momentum and coordinate representation. They have shown explicitly, that the four fermion Green function contains a pole corresponding to the Schwinger boson.
- Głazek developed a method, which may be used to solve asymptotically free models of quantum field theory using Hamiltonian approach. The key element of the method is similarity renormalization group procedure for Hamiltonians, invented and developed earlier by Głazek and Wilson. One starts from a local bare theory, which couples states from an infinite range of energy scales, and one solves perturbatively renormalization group equations (of a new type, called the similarity equations) for effective Hamiltonian operators that may be limited to physically important sectors of the space of states. The "small" limited eigenvalue problems are solved using computers.

[5]Head of division beginning March 2000.
[6]deceased May 4, 1998

- The original similarity procedure was redesigned by Głazek into a unitary transformation for quantum field operators. This way, a boost invariant theory of effective particles has emerged. Using the new method, the running coupling constants have been evaluated for the light-front Hamiltonians of scalar theories. The method is currently used to study other models and, in particular, QCD, where effective quarks and gluons of hadronic tables and partons of the parton model for hadrons in the infinite momentum frame, urgently require theoretical explanation. It is expected that the new method will help us explain quarks and gluons binding mechanisms and calculate details of structure and interaction of hadrons.

- Bartnik further investigated his method of solving bound state problems in QCD. In this approach low momenta of QCD Hamiltonian are treated explicitly, while for high momenta the usual perturbative expansion is used. In the first approximation low momentum part reduces to 27 degrees of freedom, thus making a variational estimate possible. Corresponding computer codes were developed.

- Rączka extended previous work of Rączka and Szymacha on the resummed perturbation expansion in quantum chromodynamics and performed a thorough analysis of the renormalization scheme ambiguities in the higher order corrections to the moments of the spectral functions of the correlators of vector and axial vector quark currents at low energies. Using the optimized perturbation expansion for the corrections to the hadronic decay rate of the τ lepton he determined from recent data the preferred values of the strong coupling constant at low energies and the four-fermion condensate.

PUBLICATIONS

1. *Four point Green functions in the Schwinger model*, **Radożycki, T. and Namysłowski, J.**, Physical Review D **59** (1999) 065010.
2. *Asymptotic Freedom and Bound States in Hamiltonian Dynamics*, **Głazek, S. G.** and Wilson, K. G., Physical Review D **57** (1998) 3558.
3. *Renormalization of Hamiltonians*, **Głazek, S. G.**,in Les Houches Lecture Notes, edited by P. Grangé, A. Neveu, H. C. Pauli, S. Pinsky, E. Werner, EDP-Sciences, Les Ulis; Springer-Verlag, Berlin Heidelberg 1998, p. 17-23.
4. *Similarity renormalization group approach to boost invariant hamiltonian dynamics*, **Głazek, S. G.**, Acta Physica Polonica B **29** (1998) 1979.
5. *Fourth-order similarity renormalization of a model Hamiltonian*, **Masłowski, T. and Więckowski, M.**, Physical Review D **57** (1998) 4967.
6. *Boost invariant running couplings in effective hamiltonians*, **Głazek, S. G.**, Physical Review D **60** (1999) 105030.
7. *Renormalization scheme dependence and the problem of the determination of α_s and the condensates from semileptonic τ decays*, **Rączka, P. A.**, Physical Review D **57** (1998) 6862.
8. *Improved perturbation expansion in QCD*, **Rączka, P. A.**, preprint IFT-12/99, to appear in *Proceedings of the Conference Moshe Flato 1999*, edited by G. Dito and D. Sternheimer, Kluwer Academic Publishers.

SCIENTIFIC DEGREES

M.SC.

- Jarosław Młynik, *Perturbative renormalization group for hamiltonians and the problem of optimal choice of similarity transformation*, 1999. (Supervisor: S. Głazek)

14 DIVISION OF THEORY OF SOLID STATE

Head: Prof. Jan Blinowski
Academic teachers: Dr hab. Witold Bardyszewski, Dr Krzysztof Byczuk, Dr hab. Jerzy Krupski, Dr Jakub Tworzydło
Postgraduate students: Mirosław Prywata, Maria Sobol, Rafał Wysocki

SCIENTIFIC ACTIVITIES

One of the main research interests in the modern condensed matter theory is a study of correlated electron systems. Collective behavior of interacting electrons, beyond simple one electron picture, has been realized to be crucial in describing properties of very diverse materials. The most studied examples are high T_c superconductors, low dimensional semiconductor systems and magnetic materials. The electron-electron interaction leading to their collective behavior is believed to be a cause for exotic phases in HTCS (strange metal, unusual superconductor, stripe phase, pseudo-gape phase etc.) and in transition metal oxides, in particular in the presence of impurities. The world of low dimensional electron systems manufactured from semiconductor heterostructures extends now from high-mobility 2d electron gas, via quantum wires down to quantum dots. New opportunities have been opened by discovery of carbon nanotubes: ideal one dimensional quantum wires. The importance of electron interactions in semiconductor systems is of both academic interest as well as industrial one, especially in the field of active optical devices. All magnetic properties of matter are fundamentally caused by quantum effects involving interacting electrons, new chapter in this domain started with the improved technology of low dimensional magnetic structures. All the systems enumerated above have been studied in our group in collaboration with physicists from many other polish and foreign scientific institutions. Quantum description of dissipative systems and the propagation of elastic waves in random media formed separate additional subjects of interest not directly related to the main stream of our activities.

SCIENTIFIC ACHIEVEMENTS

- Single- and two-particle properties of correlated electrons forming the spin-charge separated Luttinger liquid in a magnetic field were described, possible application of this system to the modeling of high T_c superconductors were indicated. (Byczuk)
- A quantitative theory of electroabsorption and electrorefraction in multiple quantum wells with built in strains was developed for accurate modeling of Mach-Zehnder modulators. (Bardyszewski)
- Theory of many-body effects in highly excited semiconductors and lasers has been worked out. (Bardyszewski, Prywata)
- A simple model accounting for many-body effects in X-ray absorption fine structure has been developed. (Bardyszewski)

- Electronic sub-band structure of δ-doped semiconductor has been determined by the Thomas-Fermi-Dirac method and in the more laborious self-consistent approximation. (Krupski)
- It was studied how the band nonparabolicity reduces the mobility of 2D electron gas in δ-doped semiconductor. (Krupski)
- An effective Coulomb interaction in a quantum wire made of a semiconductor with extremely large dielectric constant has been derived and shown to affect the properties of the 1d system of interacting electrons. (Byczuk)
- The puzzling results concerning spin configurations in carbon nanotubes have been theoretically explained by taking into account the spatial nonuniformity of external potentials. (Byczuk)
- The decay of quasiparticles in quantum dots has been described using the non-Caley-tree model. (Tworzydło)
- A coupled spin-ladder model has been applied to study the quantum magnetism in stripe phases in relation to the zero-temperature critical point for a transition from the superconducting to the stripe phase. (Tworzydło)
- The coupling between both ferro- and antiferromagnetic layers mediated by valence-band electrons in all-semiconductors superlattices has been calculated within a tight-binding model. (Blinowski)
- The scale-dependence of the velocity of the seismic waves has been explained in terms of a nonperturbative model of the propagation in the medium with the random velocity fluctuations. (Tworzydło)
- An original method of quantization of equations of motion for dissipative systems has been proposed. (Wysocki)

PUBLICATIONS

1. *Resonant-level effects in the absorption spectra of shallow quantum wells*, **W. Bardyszewski**, C. Rolland, S. Bradshaw and D. Yevick in *Conference on Lasers and Electro-Optics* Vol. 6, 1998 OSA Technical Digest Series (Optical Society of America, Washington DC,1998) pp.469-470.
2. *Resonant exciton contributions to quantum-well electroabsorption* **W. Bardyszewski**, D. Yevick, C. Rolland i E. Dupont, Phys. Rev. B60, 16563 (1999)
3. *Interlayer exchange in antiferromagnetic–nonmagnetic semiconductor superlattices*, H. Kepa, **J. Blinowski**, P. Kacman, G. Springholz, G. Bauer, C.F. Majkrzak, T. M. Giebułtowicz, Proc. 24th. Int. Conf. on the Physics of Semiconductors, ed. D. Gershoni, World Scientific, Singapore 1999, 1199
4. *Spin-Charge Separated Luttinger Liquid in the Magnetic Field*, **K.Byczuk**, Phys.Rev.**B 57** 3821-3828, (1998).

5. *Realistic Electron-Electron Interaction in a Quantum Wire*, **K.Byczuk**, T.Dietl, Phys.Rev. **B 60**, 1507 (1999).
6. *Ballistic quantum transport in constriction of n-PbTe*, G.Grabecki, J.Wrobel, T.Dietl, **K. Byczuk**, E.Papis, E.Kamińska, A.Piotrowska, G.Springholz, M.Pinczolits, G.Bauer, Phys.Rev. **B 60**, R5133 (1999).
7. *Spectral Properties of Luttinger Liquid and Comparison Fermi Liquid*, **K.Byczuk**, J.Spałek, W.Wójcik, Molecular Phys.Rep. **20**, 39-50 (1998).
8. *Electronic Properties of High temperature Superconductors within a Phenomenological Anderson-Luttinger Picture*, **K.Byczuk**, J.Spałek, W.Wójcik, Acta Phys. Pol. **B 29** 3871-3884, (1998).
9. *Ballistic quantum transport in n-PbTe*, G.Grabecki, J.Wrobel, T.Dietl, **K.Byczuk**, E.Papis, E.Kamińska, A.Piotrowska, G.Springholz, M.Pinczolits, G.Bauer, Pro. of Conference on Semiconductors in Jerozolima (1998).
10. *Effect of band nonparabolicity on mobility in a delta-doped semiconductor*, Gonzalez LR, **Krupski J**, Pietka M, et al. Phys. Rev. B 60: (11) 7768-7771 (1999)
11. *On the accuracy of the Thomas-Fermi-Dirac method applied to sub-band structure calculations in a delta-doped semiconductor*, **Krupski J**, Pietka M, Solid State Comm. 107: (3) 141-144 (1998)
12. *Non-Cayley-tree model for quasiparticle decay in a quantum dot*, X. Leyronas, **J. Tworzydło** and C. W. J. Beenakker, Phys. Rev. Lett. 82, 4894 (1999)
13. *Quantum magnetism in the stripe phase: bond- versus site order*, **J. Tworzydło**, O.Y. Osman, C.N.A. van Duin, J. Zaanen Phys. Rev. B **59**, 115 (1999)
14. *Influence of local potentials on spin-splitting in diluted magnetic semiconductors*, Herbich M, Klopotowski L, Mac W, Stachow A, Twardowski A, **Tworzydło J**, Demianiuk M, J. of Crystal Growth 185: 992-995, (1998)
15. *Influence of local potentials on spin-splitting in diluted magnetic semiconductors*, Herbich M, Kłopotowski L, Mac W, Stachow A, Twardowski A, **Tworzydło J**, Demianiuk M, J. of Crystal growth 185: 992-995, (1998)

SCIENTIFIC DEGREES

PH.D.

- R. Doradziński *Magnetic Kondo Lattices* 1999.

M.SC.

- P. Krupinski *Wpływ swobodnych nośnikow na renormalizacje przerwy energetycznej w półprzewodnikowych studniach kwantowych* 1999.
- R. Wąsowicz *Widmo absorpcyjne dziur w studniach kwantowych GaAs/AlGaAs* 1999.

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16 LIST OF ACADEMIC TEACHERS (31.12.1999)

The following english names of university positions are admitted as equivalent to the corresponding positions of polish academic teachers:

full professor *(profesor zwyczajny)*
associate professor *(profesor nadzwyczajny)*
assistant professor *(adiunkt)*
senior lecturer *(starszy wykładowca)*
postgraduate student *(doktorant)*

The acronyms for the Divisions of the Institute (see page 2) are given in parentheses.

FULL PROFESSORS

1. Prof. Iwo Białynicki-Birula (FS)[7]
2. Prof. Jan Blinowski (SS)
3. Prof. Marek Demiański (RG)
4. Prof. Wojciech Królikowski (EP)
5. Prof. Józef Namysłowski (HL)
6. Prof. Jarosław Piasecki (FS)
7. Prof. Stefan Pokorski (EP)
8. Prof. Stanisław G. Rohoziński (NS)
9. Prof. Andrzej Szymacha (HL)
10. Prof. Andrzej Trautman (RG)
11. Prof. Krzysztof Wódkiewicz (FS)

ASSOCIATE PROFESSORS

1. Dr hab. Witold Bardyszewski (SS)
2. Dr hab. Jan Bartelski (EP)
3. Dr hab. Aleksy Bartnik (HL)
4. Prof. Stanisław Bażański (MP)
5. Dr hab. Bogdan Cichocki (FS)

[7] on leave of absence till 31.12.1998

6. Prof. Jacek Dobaczewski (NS)
7. Dr hab. Bohdan Grządkowski (EP)
8. Prof. Jan Kalinowski (EP)
9. Dr hab. Jerzy Kamiński (FS)
10. Prof. Wojciech Kopczyński (RG)
11. Dr hab. Maria Krawczyk (EP)
12. Dr hab. Jerzy Krupski (SS)
13. Dr hab. Krzysztof Meissner (EP)
14. Prof. Bogdan Mielnik (MP)[8]
15. Prof. Marek Napiórkowski (FS)
16. Prof. Witold Nazarewicz (NS)[9]
17. Dr hab. Marek Olechowski (EP)
18. Dr hab. Jacek Tafel (RG)
19. Prof. Antoni Sym (MP)

ASSISTANT PROFESSORS

1. Dr Krzysztof Byczuk (SS)
2. Dr hab. Piotr Chankowski (EP)
3. Dr Adam Doliwa (MP)
4. Dr hab. Stanisław Głazek (HL)
5. Dr Jacek Jasiak (HL)
6. Dr hab. Zygmunt Lalak (EP)
7. Dr hab. Jerzy Lewandowski (RG)
8. Dr Mikołaj Misiak (EP)
9. Dr Paweł Nurowski (RG)

[8] on leave of absence till 31.07.1999
[9] on leave of absence

10. Dr hab. Krzysztof Pachucki (SP)
11. Dr hab. Jacek Pawełczyk (EP)
12. Dr Krzysztof Rejmer (FS)
13. Dr Janusz Rosiek (EP)
14. Dr Piotr Rączka (HL)
15. Dr hab. Wojciech Satuła (NS)
16. Dr Jakub Tworzydło (SS)
17. Dr hab. Tomasz Werner (NS)

SENIOR LECTURERS

1. Dr Zygmunt Ajduk (EP)
2. Dr Maciej Pindor (EP)

POSTGRADUATE STUDENTS

1. Mgr Konrad Banaszek (FS)
2. Mgr Mariusz Bednarz (HL)
3. Mgr Mariusz Białecki (MP)
4. Mgr Rafał Ciesielski (EP)
5. Mgr Marcin Flak (EP)
6. Mgr Piotr Grzywacz (EP)
7. Mgr Adam Jakóbek (EP)
8. Mgr Paweł Jankowski (EP)
9. Mgr Agnieszka Jaroń (FS)
10. Mgr Urszula Jezuita-Dąbrowska (EP)
11. Mgr Paweł Klimczewski (MP)
12. Mgr Katarzyna Krajewska (FS)
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14. Mgr Grzegorz Kubalski (FS)
15. Mgr Jacek Litwin (RG)
16. Mgr Tomasz Masłowski (HL)
17. Mgr Jarosław Młynik (HL)
18. Mgr Mariusz Mroczek (RG)
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31. Mgr Robert Wąsowicz (SS)
32. Mgr Marek Więckowski (HL)
33. Mgr Rafał Wysocki (SS)