ANNUAL REPORT

1995

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of the Hungarian Academy of Sciences, Budapest, Hungary

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ANNUAL REPORT 1995

Edited by **L. Csillag, J. Kollár, G. Konczos, B. Selmeci**

Closed on 1st December, 1995

Dear Reader,

May I greet you on behalf of the staff of our Institute. We are glad to hand you over the second volume of our yearbook. If you meet us first we want to introduce ourselves. If however, you already know us we want to inform you on some of our latest results.

Most of our more than 100 scientists and engineers are involved in basic research in theoretical and experimental solid state physics, materials sciences, light-matter interaction and laser physics. Part of' our experimental research e.g. in metal physics and laser applications is strongly application oriented. Our research traditions go back to the fifties when we were part of a large center, namely the Central Research Institute for Physics. Since 1992 we are independent.

International cooperation is a vital part of our research. This is partly based on good personal contacts, partly on institutionalised, project oriented research. You may see that in about 50% of our publications there is at least one foreign author. Our participation in international projects, financed from foreign financial resources is unfortunately not too large yet although this could significantiy improve our financial situation which is permanently deteriorating.

The lack of finances is especially felt in the ageing of our instrumental park but our resources are strongly limited in other fields too. For your information we have given some data on our finances, including the research grants where the most significant contribution comes from the Hungarian Scientific Research Fund, OTKA. These sources make possible that we still can do good research and that we can participate in. the activities of the international research community.

Graduate and post-graduate education in solid state and laser physics, in laser applications as well as in materials sciences is considcrcd to be a significant part of our activity. Data on our participation in this field are also given.

1 hope that the present booklet will be of some use for you by briefly informing you on our goals and achievements.

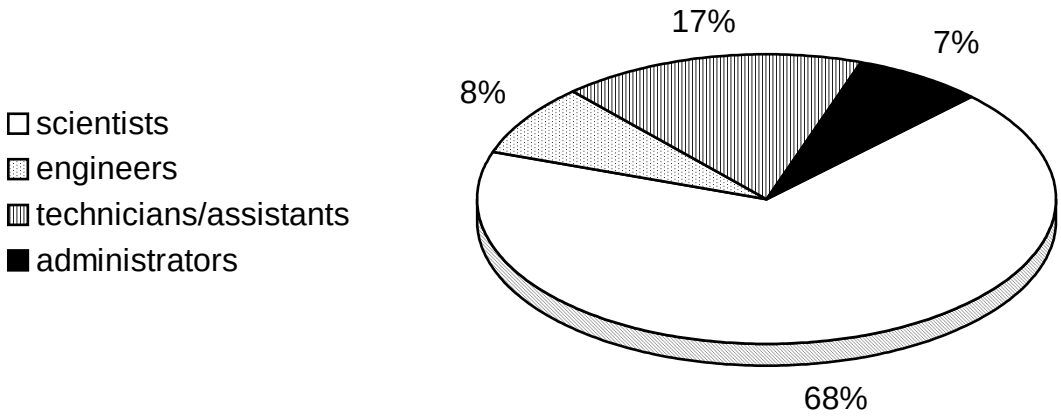
Budapest 01. 12. 1995.

Norbert Kroó
Director

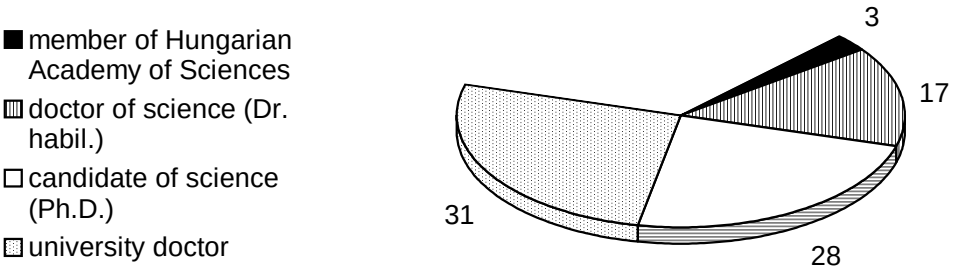
Key figures

Permanent staff of the Institute: 133 employees. Its distribution:

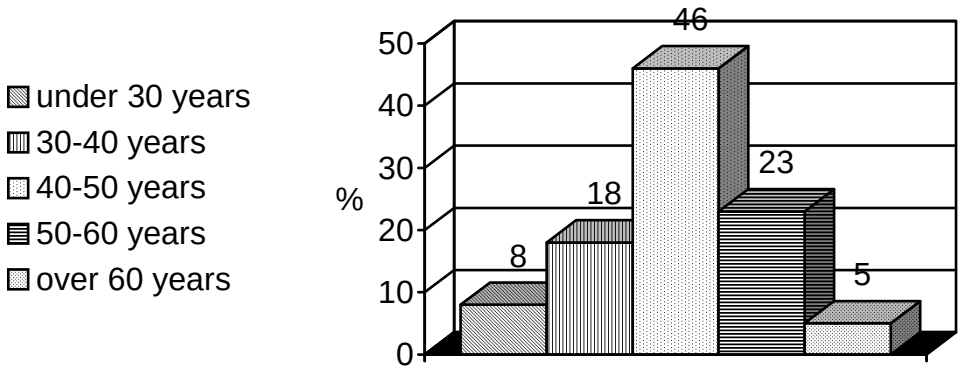
a) by professions:



b) by scientific titles/degrees:

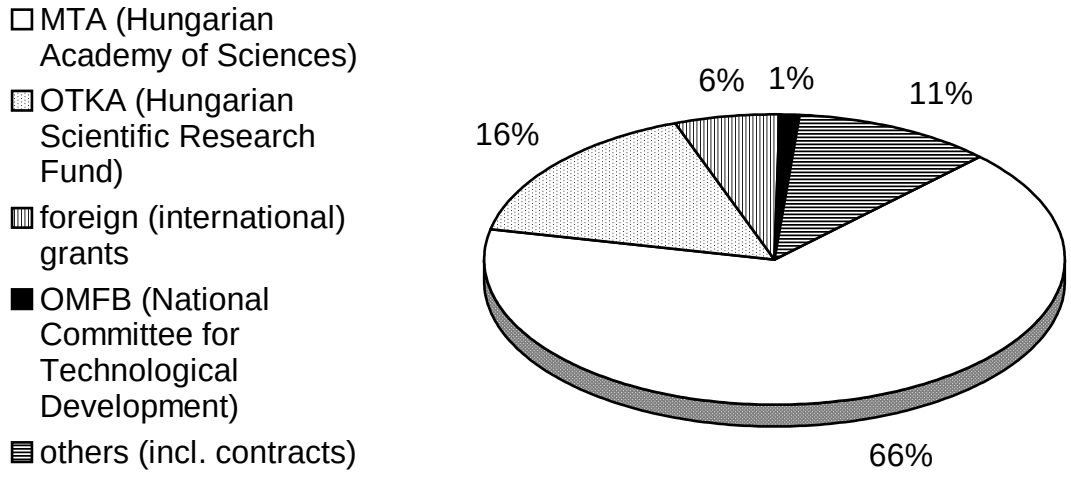


c) by ages:

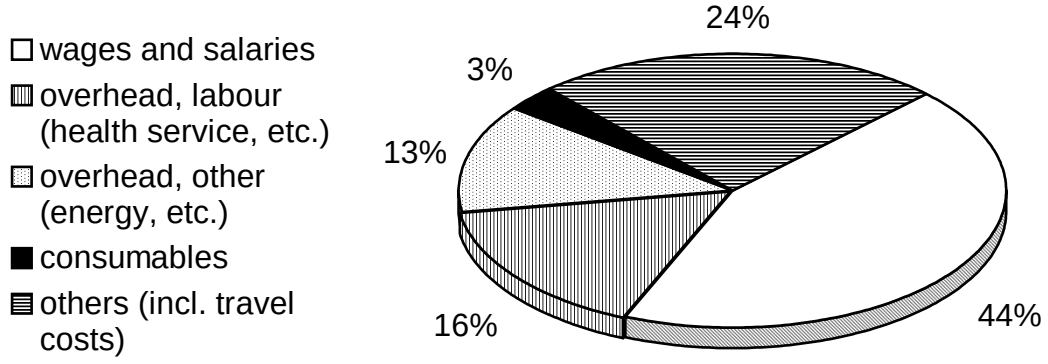


Financial management

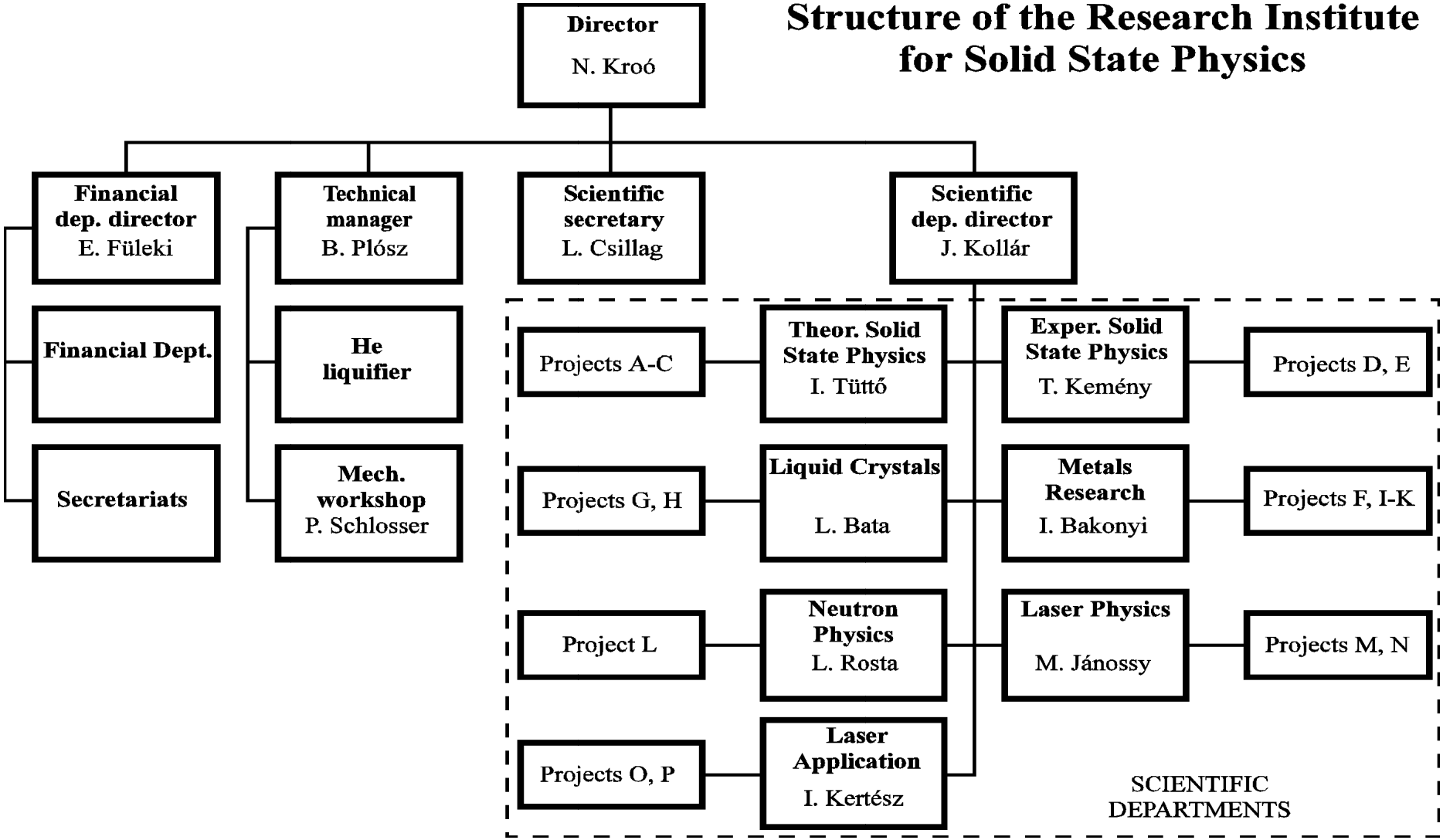
a) Sources of operation costs:



b) Distribution of expenditures:



Structure of the Research Institute for Solid State Physics



A. STRONGLY CORRELATED SYSTEMS

J. Sólyom, G. Fáth, K. Penc, K. Vladár, F. Woynarovich

Low dimensional magnetic models. — The one-dimensional Heisenberg model is known to be soluble by the Bethe Ansatz. The spectrum of a ferromagnet consists of magnons and bound state of magnons. The problem of finding the bound state of a macroscopically large number of magnons poses a special problem. These states are described by macroscopically long string solutions of the Bethe Ansatz equations. To find such solutions numerically we developed a program by which even chains of several hundred sites can be treated. Our results show that, as expected, the structure of the macroscopically long strings is not of the Bethe-type.

Recently several new materials have been discovered in which the localized magnetic moments are situated in a chain like structure. The energy spectrum and the behaviour of these systems depends strongly on the value of the spin and the number of coupled chains. We started to study these models using the density matrix renormalization group.

One-dimensional fermionic models. — The Hubbard model is the simplest model of the interacting electron system. It is usually formulated on a discrete lattice. Sometimes it is more appropriate to work in the continuum limit. We have shown, that the continuum limit of the Hubbard chain, in which the particle number per site is kept constant leads to a relativistic model describing both finite and zero mass particles. By constructing the relativistic limit of the half-filled band we have shown, that also the relativistic particles are described by Bethe-Ansatz type equations, while in the relativistic limit of the non-half-filled chain this is true only for the massive particles, and the equations of the massless particles are of somewhat different structure.

Theory of dissipative motion of heavy particles. — We studied the low energy fixed point structure of an N_f-flavor two level system (TLS) model, where the spin of the conduction electrons is replaced by a flavor quantum number, $f = 1, \ldots, N_f$. Using the multiplicative renormalization group we constructed the $(1/N_f)^2$ order scaling equations and we analyzed their fixed point structure. We showed that the fixed point structure of this Hamiltonian is equivalent to that of the N_f-channel Kondo model and we found that the exponent of the leading irrelevant operators is also the same. However, for a TLS an infinite number of leading irrelevant operators appear which give a contribution to the different physical quantities but do not change their critical exponents.

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Ferenc Woynarovich	fw@ power.szfki.kfki.hu

Grants

OTKA[1] I/3 2979. Low dimensional magnetic systems and high temperature superconductivity
OTKA I/4 T4473. Low dimensional interacting electon systems and magnetic models.
OTKA T 014443. Completely integrable 1-d systems
OTKA T 015870. Models of strongly correlated low-dimensional electron systems
OTKA T 017128. Theoretical study of dissipative motion of heavy particles

Publications[+]

Articles

A.1. G. Fáth, J. Sólyom: Search for the nondimerized quantum nematic phase in the spin-1 chain. Phys. Rev. B **51**, 3620 (1995).

A.2. K. Penc, H. Shiba[*]: Propagating S=1/2 particles in S=1 Haldane gap systems. Phys. Rev. B **52** (Rap. Comm.), R715 (1995).

A.3. K. Penc, F. Mila[*], H. Shiba[*]: Spectral function of the 1D Hubbard model in the $U \to \infty$ limit. Phys. Rev. Lett. **75**, 894 (1995).

A.4. F. Mila[*], K. Penc: Susceptibility of the one--dimensional dimerized Hubbard model. Phys. Rev. B **51** (Rap. Comm.), 1997 (1995).

A.5. J. Sólyom and K. Penc: Relationship among the Hubbard, t-J and Tomonaga-Luttinger models. In: *Recent Progress in Many Body Theories*, Vol. 4. Eds. E. Schachinger, H. Mitter and M. Sormann , Plenum Press, 1995 pp 263-270.

A.6. F. Woynarovich: Massive particles in the relativistic limit of the non-half-filled 1D attractive Hubbard model. To be published in J. Phys. A as a "letter to the editor".

A.7. G. Zaránd and K. Vladár: Low temperature dynamics of an N_f-flavor two level system in a metal: Equivalence with the N_f-channel Kondo model in the $(1/N_f)^2$ order. To be published in Physical Review Letters.

[1]OTKA = Hungarian Scientific Research Fund
[+] The *Annual Report* contains publications appeared or accepted by the publishers in the period 1 December 1994-30 November 1995
[*] The author is not a member of the Research Institute for Solid State Physics staff

B. COMPLEX SYSTEMS

N. Menyhárd, A. Csordás, F. Iglói, A. Sütõ, P. Szépfalusy[+]

The principal interest of this group is the theoretical investigation of different aspects of equilibrium and non-equilibrium statistical physics

Phase transitions and scaling - equilibrium and non-equilibrium. — The quasicrystal is a new state of matter which can be characterised by short range disorder and long range correlations. Artificial, layered systems with quasiperiodic or more generally aperiodic or hierarchical structures can be built by multilayer techniques. An interesting theoretical question is the nature of phase transitions in such systems.

We have investigated layered Ising models with different types of structures and determined exactly the critical exponents, both at the surface and in the bulk. If the aperiodicity represents a marginal perturbation which extends over the volume of the system, then close to the critical point the system becomes essentially anisotropic: the correlation length diverges with different exponents along and perpendicular to the layers. For surface marginal perturbations, which do not modify the bulk behaviour, we have shown that the system remains conformally invariant at the critical point.

In non-equilibrium phase transitions similarities with and differences from equilibrium systems are questions much investigated. In this context kinetic Ising models offer a useful laboratory also for exploring the different factors which influence scaling and (dynamic) universality classes. We have introduced earlier a family of nonequilibrium kinetic Ising models which show a phase transition from Ising-type steady state to an active state belonging to a new dynamic universality class. The phase boundary, a line of second order phase transition points, has been shown now to end up in a first order tricritical point which is of mean-field type.

An extension of expansion theorems is suggested for correlation functions at high temperatures and low fugacities in classical continuous systems interacting via an unstable interaction. A toy model for crystallization has also been presented

Classical and quantum chaos. — Transient chaos has come into the focus of interest lately, both experimentally and theoretically. We have investigated several statistical properties of transient chaos, especially the extension of the intermittent state occurring in permanent chaos to transient chaos. It has been shown that in this state a phase transition-like phenomenon takes place, which is continuous, as opposed to the first-order transition occurring in the intermittent state of permanent chaos.

The other main subject of our research has been the quantum mechanical analysis of a supersymmetrically extended chaotic cosmological model. We have found completely new wave-functions in the two and four-fermion sectors.

Quantum systems. — A comprehensive review of WKB theory for mesoscopic quantum tunneling in magnetism has been presented.The behaviour of a large quantum spin in an anisotropic surroundings and its penetration into a classically forbidden region is described. The key idea is to single out one of the anisotropy axes say z, work in a representation with z diagonal and to describe quantum tunneling as a hopping process on the spectrum of z. A review of recent developments in the theory of one-dimensional tight-binding Schrõdinger equation for a class of deterministic

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ergodic potentials has been given. In the typical examples the potentials are generated by substitutional sequences, like Fibonacci or Thue-Morse sequences.

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Grants:

OTKA F4472	Classical and quantum dynamics of non-linear systems
OTKA T12830	Critical behaviour of low-dimensional systems
OTKA T17493	Theory of random processes and complex structures
OTKA T14855	Phase transitions and spectral problem in quantum systems

Publications

Articles

B.1. B. Berche*, P-E. Berche*, M. Henkel*, F. Iglói, P. Lajkó, S. Morgan*, L. Turban*: Anisotropic Scaling in Layered Aperiodic Ising Systems. J. Phys. **A28**, L165 (1995)

B.2. B. Berche*, F. Iglói: Realization of Supersymmetric Quantummechanics in Inhomogeneous Ising Models J. Phys. **A28**, L165 (1995)

B.3. F. Iglói, P. Lajkó, F. Szalma: Critical Behaviour of Hierarchical Ising Models Phys. Rev. **B52**, 7159 (1995)

B.4. D. Karevski*, L. Turban*, F. Iglói: Radial Aperiodic Perturbation in the Two-Dimensional Ising model and Gap-Exponent Relation J. Phys. **A28**, 3925 (1995)

B.5. N. Menyhárd, G. Ódor: Non-equilibrium phase transitions in one-dimensional kinetic Ising models. J.Phys.A: Math.Gen. **28**, 4505 (1995)

B.6. A. Németh*, P.Szépfalusy: Properties of border states of transient chaos. Phys.Rev. **E52**, 1544 (1995)

B.7. A. Csordás, R. Graham*: Supersymmetric minisuperspace with non-vanishing fermion number. Phys. Rev. Lett. **74**, 4926 (1995)

B.8. A. Sütõ: Schrõdinger difference equation with deterministic ergodic potentials. In: *Beyond Quasicrystals*, eds. F Axel and D. Gratias, Les Editions de Physique, Springer: Les Houches Series **3**, 481-549 (1995)

B.9. A. Sütõ: Low density expansion for unstable interactions and a model of crystallization. To be published in J. Stat. Phys.

B.10. F. Iglói, P. Lajkó: On the Critical Temperature of Ising Models on Hexagonal Lattices. To be published in Z. Phys. B

B.11. A. Csordás, R. Graham*: Exact quantum state for N=1 supergravity. To be published in Phys. Rev. D.

B.12. J.L. van Hemmen*, A. Sütõ: Theory of mesoscopic quantum tunneling in magnetism: a WKB approach. In : *Quantum Tunneling of Magnetism*, eds. L.Gunther and B. Barbara (Kluwer,1995) pp. 19-57

Conference proceeding

B.13. A. Csordás, R. Graham*: Nontrivial Fermion States in Supersymmetric Minisuperspace. To be published in: *Proceedings of the First Mexican School on Gravitation and Mathematical Physics, Guanajuto, GTO., Mexico (1995)*

C. ELECTRONIC STATES IN SOLIDS

J. Kollár, P. Fazekas, I. Tüttõ, B. Újfalussy, A. Virosztek, L. Vitos

Our recent activities cover the following main areas in the description of the electronic states in solids:

- We have improved our recently developed **full charge density scheme** by determining the non-spherical charge density more accurately within the space-filling, non-overlapping cells in a solid. This technique has been applied to calculate the atomic volumes of the light actinides including Fr, Ra, and Ac in their low temperature crystallographic phases. The good agreement between the theoretical and experimental values along the series supports the picture of itinerant 5f electronic states in Th to Pu. The increased deviation between theory and experiment found in Np and Pu may be an indication of correlation effects not included in the local density approximation. We have examined the structural stability of different crystallographic phases of these elements as well, and found close resemblance to the observations.
- We studied the **magnetic properties of surfaces and interfaces**. The magnetic properties of mono- and double layers of Ru, Rh, Pd, Os, Ir and Pt on Ag(001) and Au(001) are investigated using the scalar--relativistic and the fully relativistic spin--polarized screened KKR method. It is shown that, in particular, for the case of the Ir monolayers and Pt double layers a non--relativistic approach is no longer valid, since a magnetic ground state would be predicted, while a relativistic description yields a non-magnetic ground state. The magneto-crystalline anisotropy of magnetic overlayers is a very interesting and technologically important field in solid state physics. Here we calculated the magneto-crystalline anisotropy up to 6 Fe overlayers on Au(001) and predicted a change from a perpendicular to a parallel magnetization for layer thickness between 3 and 4 layers of Fe, in very good agreement to experimental observations. These calculations were done by the screened KKR method, which we also improved and layed on a mathematically exact basis by using the concept of scattering reference systems.

  Based on the **nested Fermi liquid theory** we performed a detailed analysis of the infrared and microwave spectra of **high temperature superconductors**, this time in the superconducting state. We concluded that phonon mediated pairing is unable to explain the experiments, and invoked a pairing mechanism of electronic origin. Further investigation of this paramagnon exchange mechanism revealed that it favours *d*-wave pairing in highly anisotropic systems. This conclusion is corroborated by an analysis of the B_{1g} Raman phonon lineshape, in the framework of a realistic three band model of the cuprates.

  We have developed a theory of electron-phonon coupling in quasi one dimensional **charge- and spin-density wave materials**, which enabled us to investigate the interaction of various phonon modes (sound waves) with the density wave condensate. Including long-range Coulomb interaction as well, we have shown that only the transverse sound wave polarized in the chain direction couples to the condensate, therefore only in this case do we expect the electromechanical effect .

– We continued the study of multiband models of **strongly correlated electron systems**. Our variational description of a generalized Fu-Doniach- type model gave preliminary results on the nature of FeSi-like correlated insulating states, and - at finite doping - on band ferromagnetism (in collaboration with K. Itai) .

– Considering the coexistence of the **superconducting and spin density wave states**, we derived a direct coupling between these two condensed states. As a consequence of this mixing, the amplitude modes of these states show up in the Raman spectrum. Furthermore, we have shown that in the **layered superconductors** the Josephson coupling between the layers strongly modifies the gap structure and other electronic properties of these materials .

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Grants

OTKA 2950	Electronic structure and the calculation and measurement of optical spectra in solids
OTKA T016740	Electronic states in complex structures (solids, surfaces and interfaces)
OTKA T4473	Low dimensional interacting electron systems and magnetic models
OTKA T014201	Theory of phase diagrams of heavy fermion systems

Publications

Articles

C.1. L. Vitos and J. Kollár: Optimized l-Convergency in the Solution of Poisson's Equation with Space-Filling Cells, Phys. Rev. B, **51**, 4074 (1995)

C.2. B. Újfalussy, L. Szunyogh*, P. Weinberger*: Magnetism of 4d and 5d adlayers on Ag(001) and Au(001): Comparison between a nonrelativistic and a fully relativistic approach, Phys. Rev. B **51**, 12836 (1995)

C.3. L. Szunyogh*, B. Újfalussy, and P. Weinberger*: Magnetic anisotropy of iron multilayers on Au(001): first principles calculations in terms of the fully relativistic spin-polarized screened KKR method, Phys. Rev. B **51**, 9552 (1995)

C.4. R. Zeller*, P.H. Dederichs*, B. Újfalussy, L. Szunyogh*, P. Weinberger*: Theory and convergence properties of the screened Korringa--Kohn--Rostoker method, Phys. Rev. B **52**, 8807-8812 (1995)

C.5. T. P. Devereaux*, A. Virosztek and A. Zawadowski: Charge Transfer Fluctuation, d-wave Superconductivity, and the B_{1g} Raman Phonon in the Cuprates, Phys. Rev. B **51**, 505 (1995)

C.6. C. T. Rieck*, W. A. Little*, J. Ruvalds*, A. Virosztek: Infrared and Microwave Spectra of an Energy Gap in High Temperature Superconductors, Phys. Rev. B **51**, 3772 (1995)

C.7. J. Ruvalds*, C. T. Rieck*, S. Tewari*, J. Thoma*, A. Virosztek: Nesting Mechanism for d-symmetry Superconductors, Phys. Rev. B **51**, 3797 (1995)

C.8. A. Virosztek and K. Maki*: Electromechanical Effect in Charge- and Spin-density Waves, Synth. Metals **70**, 1283 (1995)

C.9. P.Fazekas: Magnetic and non-magnetic states of heavy fermion systems. In: *Superconductivity and Strongly Correlated Fermion Systems*, Eds. C. Noce, A. Romaurs and G. Scarpetta, Word Scientific, p 325, (1994)

C.10. L. Vitos, J. Kollár and H.L. Skriver*: Energetics of the light actinides in a full charge density scheme. To be published in *Nato ASI Series: Stability of Materials*, Eds. A. Gonis, P.E.A. Turchi and J. Kudrnovsky, Plenum Press, 1995

C.11. L. Vitos, J. Kollár and H.L. Skriver*: *Ab initio* full charge density study of the atomic volume of α-phase Fr, Ra, Ac, Th, Pa, U, Np, and Pu. To be published in Phys. Rev. B

C.12. B. Újfalussy, L. Szunyogh*, P. Weinberger*: Fully relativistic spin-polarized description of interface exchange coupling for Fe multilayers in Au(001). To be published in J. Magn. Magn. Mater. (1995)

C.13. A. Virosztek and K. Maki*: Sound Propagation in Density Wave Conductors and the Effect of Long-range Coulomb Interaction. To be published in Phys. Rev. B

D. NON-EQUILIBRIUM ALLOYS

I. Vincze, J. Balogh, L. Bujdosó, D. Kaptás, T. Kemény, L.F. Kiss, Gy. Mészáros, B. Sas, E. Sváb

Spin-glasses. — Spin freezing is manifested in the disappearance of magnetization measured at low temperatures and in low applied magnetic fields. It is correlated with the absence of magnetic saturation even in large external fields. Composition, temperature and external magnetic field dependent studies of the magnetic properties of the magnetically concentrated amorphous $Fe_{100-x}Zr_x$ ($7 \leq x \leq 12$) were performed. On the base of these experimental data a new phenomenological explanation of the magnetic anomalies was proposed. Essential assumption of this model is that the magnetic moments of iron atoms with only iron nearest neighbourhood are decoupled from the ferromagnetic matrix. It is explained by the compressed atomic volume of these iron atoms. The decoupling results in bond percolation: ferromagnetic couplings are dissected by the statistical occurence of these iron-rich environments. The other important feature of this model is the shape anisotropy of these percolation clusters. This random magnetic shape anisotropy results in the freezing of collinearly correlated regions and gives a natural explanation for the unusual sensitivity of magnetic properties to the applied field which is not properly taken into account in former models.

Certain analogies are observed in the magnetic behaviour of small particles, very thin magnetic layers and nanocrystalline magnetic materials and they are explained by the increased role of shape anisotropy as the common feature.

Relaxation procesess. — Reversible relaxation spectra of Fe(-Ni)-B and Fe-Ni-P metallic glasses were investigated by differential scanning calorimetry (DSC). Qualitative difference was observed between the spectra of the B- and P-containing amorphous alloys. While in the Fe(-Ni)-B glasses the relaxation spectrum is an exponential function of the activation energy (E), that of the Fe-Ni-P glasses shows a maximum vs. E. This way the dominant contribution to the relaxation spectrum comes from much lower E values than in the boron based glasses. This difference is thought to be of structural origin, though characteristic differences between the structure of P- and B-containing glasses cannot be observed by direct methods. New insights into this phenomenon are expected from computer simulations.

Non-equilibrium alloy formation. — Besides the solid state reaction processes utilised in ultra high vacuum (UHV) evaporated multilayers and in controlled atmosphere mechanical milling of elemental components and intermetallic compounds, the nanostructures formed by the crystallization of melt spun amorphous alloys are also investigated. The composition, spatial extension and thermal stability of the non-equilibrium phases are investigated by Mössbauer spectroscopy, synchrotron radiation X-ray diffraction, electron microscopy and differential scanning calorimetry. Beyond the basic problems of formation, atomic and electronic structure and magnetic properties, the potential use of microstructures for soft magnetic applications is also considered.

Neutron Scattering. — Short range structure of amorphous $(Ti\text{-}Zr)_{86}Si_{14}$ was investigated by neutron diffraction. Due to the negative scattering amplitude of titanium the partial correlation functions were obtained using isomorphous substitution. The partial Si-Si atomic correlation function, the GNN(r) and GCC(r)

correlation functions of the Bhatia-Thornton formalism were obtained. These functions characterize the topological and chemical short range ordering, respectively. A semi-empirical fitting procedure has been developed and utilized in analysing the characteristic features of the partial structure factors of amorphous alloys. An analytical formula is given to fit the experimental atomic pair correlation function as a sum of Gaussians. The inverse Fourier transform of the fitted terms reproduces all features of the experimental structure function. In addition to the structural parameters, the modelling gives a quantitative explanation for the complex origin of characteristic features in the diffraction pattern as pre-peak, pre-minimum, and splitted peaks in the partial structure factor.

Detailed structure study was performed on $(Ni_xCo_{(1-x)})_3O_4$ ($0.25<x<0.82$) spinels by neutron diffraction, with special respect to determine the cation distribution. From Rietveld-refinement it was shown that the system is a partly inverse type spinel.

Dynamic neutron radiography investigations were carried out on fire-extinguishers and various new models of absorption and compression type refrigerators with the aim of development.

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Imre Vincze	vincze@ power.szfki.kfki.hu

Grants

Copernicus COP 753	Manufacture, structure and properties of amorphous and nanocrystalline materials
OTKA I/4 T 4464	The effect of the distribution of local magnetic properties to the magnetic order
OTKA I/4 T 4469	Atomic level alloying
OTKA I/7 T 017456	The spin glass behaviour and its relation to the magnetic properties of nanostructures.
OTKA I/7 T 017129	Metastable systems investigated by neutron scattering

Publications

Articles

D.1. J. Balogh, T. Kemény, I. Vincze, L. Bujdosó, L. Tóth* and G. Vincze*: Amorphous alloy formation by mechanical alloying and consecutive heat treatment in $Fe_{50}B_{50}$ powder mixture. Journal of Applied Physics **77**, 4997-5003 (1995)

D.2. J. Balogh, L. Bujdosó, Gy. Faigel, T. Kemény and I. Vincze: Solid state amorphization in the Fe-B system. Materials Science Forum **179-181**, 775-780 (1995)

D.3. L. F. Kiss and N. Hegman*: Frequency dependence of ac susceptibility of amorphous $Fe_{93}Zr_7$ alloy. Journal of Magnetism and Magnetic Materials **140-144**, 293-294 (1995)

D.4. I. Vincze, D. Kaptás, T. Kemény, L.F. Kiss, J. Balogh: Temperature and external magnetic field dependence of the spin freezing in amorphous $Fe_{93}Zr_7$. Ibid. **140-144**, 297-298 (1995)

D.5. M. Balaskó*, E. Sváb, I. Cserháti*, F. Ozsvári*, J. Oláh*. Applications of dynamic neutron and gamma radiography at the Budapest Research Reactor. Acta Physica Hungarica **75**, 227-230 (1994)

D.6. S.N. Ishmaev*, E. Sváb: Static and dynamic atomic correlations in amorphous systems. Ibid. **75**, 117-122 (1994)

D.7. E. Sváb, S. Borbély, Gy. Mészáros, S.N. Ishmaev*, R. Glas*: Small-angle neutron scattering study of amorphous isotopic Ni-Nb system. Ibid. **75**, 267-272 (1994)

D.8 M. Balaskó*, E. Sváb: Dynamic neutron radiography instrumentation and applications in Central Europe. To be published in Nucl. Instr. Meth. A.

D.9 A. Böhönyey*, L.F.Kiss, A. Lovas, Reversible relaxation spectra of (Fe-)Ni-P metallic glasses, To be published in J. Non-Cryst. Solids (1995)

D.10. L.F. Kiss, G. Huhn*, T. Kemény, J. Balogh and D. Kaptás: Magnetic properties of Fe-Zr metastable phases, To be published in Journal of Magnetism and Magnetic Materials

D.11. E. Sváb, F. Hajdu, Gy. Mészáros: Semi-empirical fitting of partial pair correlation functions for amorphous alloys. To be published in Z. Naturforsch. A.

D.12. E. Sváb, Gy. Mészáros, F. Deák: Neutron powder diffractometer at the Budapest Research Reactor. To be published in Materials Science Forum

Conference proceedings

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See also E16, E27, J5, L8

E. X-RAY DIFFRACTION

G. Faigel, G. Bortel, L. Gránásy, K. Kamarás, G. Oszlányi, S. Pekker, T. Pusztai, M. Tegze

Alkali fullerides. — The fullerenes are closed shell molecules containing only carbon atoms. The most abundant among them is the C_{60} molecule. Fullerenes can form a large variety of compounds with elements or other molecules. In the group of A_xC_{60} compounds (A=K,Rb,Cs x=1,3,4,6) there are materials with very interesting properties. Among them many superconducting materials (A_3C_{60}) with remarkably high critical temperature were found. Recently, the A_1C_{60} type compounds became the center of interest.

A_1C_{60} compounds. In the A_1C_{60} system (A=K,Rb,Cs) several different phases were found as a function of temperature. These phases show unexpected structural and transport properties. They have a rock salt structure at high temperature (400K) and they are conductors. Slowly cooling them to room temperature they transform to an orthorhombic phase via a first order phase transition. We determined the atomic structure of this phase, and found that a polymer state developed. We have been able to grow small (few mm in length) single crystals of the K_1C_{60} polymer. Partial oxidation under toluene transformed these crystals into bundles of fibers. The degree of polymerization exceeded 100,000. When these compounds, instead of slow cooling, quenched to low temperatures, a different orthorhombic phase develops. In this metastable phase the C_{60} molecules are connected in pairs: a dimer state is formed. On heating, the dimer state transforms first to a cubic monomeric state, then to the polymer state. On further heating the polymer decomposes to the high temperature rock salt phase. The only exception is the K_1C_{60} compound. In this case the polymer first transforms to an intermediate state. This intermediate state contains alkali free and K_3C_{60}-like regions with a continuous C_{60} sublattice. We have also studied the thermodynamics and kinetics of these phase transitions by DSC and IR spectroscopy.

A_3C_{60} compounds. Rb_xC_{60} samples containing the superconducting Rb_3C_{60} phase were studied by x-ray diffraction and magnetic susceptibility measurement. It was found that in the samples with overall composition $x < 3$ the lattice parameter and the superconducting temperature of the Rb_3C_{60} phase are reduced. We attribute the change to the appearance of vacancies at the Rb sites. There is a similar correlation between T_c and the lattice parameter as was found for compounds with different alkali metals or at different pressures.

X-ray resonant scattering. — Scattering of hard x-ray or gamma-ray photons on atomic nuclei have a significant cross section when the energy of the photon is the same as the difference between two energy levels of the nucleus. This resonant scattering is closely related to the Mössbauer effect. A resonant scattering experiment can be done by using radioactive (Mössbauer) source or synchrotron radiation.

Mössbauer diffraction measurement on polycrystalline samples. It was demonstrated in the early days of Mössbauer spectroscopy that coherent scattering of photons emitted by a Mössbauer source can be observed. In spite of the fact that scattering experiments could give information not accessible by the absorption method they are not widely used due to experimental difficulties. We have designed and built a diffractometer which makes feasible Mössbauer diffraction experiment on powder and polycrystalline samples on a time scale of few days with a moderately strong

radioactive source. We have performed Mössbauer diffraction experiment on polycrystalline bcc iron. We have demonstrated that using the kinematical theory of gamma ray diffraction, useful information can be obtained on the relative orientation of crystallographic axis to the hyperfine field directions.

X-ray resonant forward scattering of synchrotron radiation on ^{151}Eu. Synchrotrons – unlike Mössbauer sources – emit x-rays in a wide energy range. A successful resonant scattering experiment requires the very good (meV range) monochromatization of the synchrotron radiation. In collaboration with the European Synchrotron Radiation Facility (Grenoble) and the Institute of Experimental Physics of the University of Hamburg, we have designed and built a silicon single crystal x-ray monochromator working at the 21.5 keV energy of the Mössbauer transition of the ^{151}Eu nucleus. We have started experiments to detect delayed x-ray photons.

Nucleation theory. — The applicability of the diffuse interface theory of crystal nucleation developed earlier was tested for various substances including hydrocarbons, liquid metals, water, oxide and metallic glasses. It has been demonstrated that the theory is consistent with data on a great variety of substances (15 compositions), and describes the experiments significantly better than the classical theory. In the case of ice nucleation in undercooled water, structural changes of water responsible for its anomalous behavior were taken into account. A semi-empirical van der Waals/Cahn-Hilliard model of vapor condensation has been developed. The cross-interfacial distributions of local thermodynamic quantities were determined for planar and spherical geometry.

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Grants

OTKA T4222 Preparation and physical properties of fullerene derivatives
OTKA T4226 Nuclear resonant scattering of gamma photons on periodic systems
OTKA T4474 Electrical properties of conducting fullerenes
OTKA T016057 Preparation and structural, optical and thermal studies of fullerenes and related materials
OTKA T017485 Theoretical investigation of nucleation processes
PHARE ACCORD H9112-0522 Participation in the nuclear resonant scattering (Mössbauer) program of the European Synchrotron Radiation Facility at beamline No. 11
EC Copernicus CIPA-CT93-0032 Technology and optical properties of high temperature superconductors
U.S.-Hungarian Joint Fund 225 Single crystal C_{60} spectroscopy

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See also D2, D20

F. CHARGE- AND SPIN-DENSITY WAVES

G. Kriza, A. Beleznay, G. Mihály[+]

Quantum Hall effect in bulk crystals. — The only bulk crystals in which quantum Hall effect has been observed are the so-called Bechgaard salts $(TMTSF)_2X$, where TMTSF stands for the organic molecule tetramethyltetraselenafulvalene, and X stands for a monovalent anion, e.g., PF_6, ClO_4, etc. These are strongly anisotropic conductors with correlated ground states: superconductor or spin-density wave. In the best-known member of the family, $(TMTSF)_2PF_6$, quantum Hall effect is observed if the anisotropy is reduced by the application of a sufficiently high hydrostatic pressure. At high pressures, the sequence of the indices of the integer quantum Hall phases with increasing magnetic field is regular: L = ... 3, 2, 1,... Upon decreasing the hydrostatic pressure, however, we have found a surprising irregular sequence: L = ...3, –2, 2, 1. We have investigated the temperature–magnetic field–pressure phase diagram of this novel phase exhibiting a negative quantum Hall plateau, and interpreted our findings in the framework of recent theories of the quantum Hall effect in magnetic-field-induced spin-density waves.

Technical developments. — As part of the modernization of the solid state NMR spectrometer at the Research Institute for Solid State Physics, a high-homogeneity superconducting magnet has been purchased from Oxford Instruments (Oxford, UK). The magnet has the following characteristics:

- 9-tesla central field,
- 88-mm room-temperature bore,
- 1 ppm field homogeneity over 10-mm diameter sample volume,
- de-mountable current leads (fitted with high-stability superconducting switch),
- ultra low loss dewar (hold time approximately 30 days).

The magnet arrived to Budapest in August, and it is being installed at present in cooperation with other teams of the Metal Physics Department. We expect it to be a fully operational part of the NMR spectrometer by January 1996. The new superconducting magnet represents a fourfold increase in the available NMR frequency, opening the way to many new fields of research.

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Grants

OTKA T7277: Dielectric properties of coherent density waves
NSF–Hungarian Acad. Sci. Travel Grant: Effect of Disorder on the Spin-Density Wave Excitations
Bilateral Cooperation Fund provided by the NWO of the Netherlands: Electronic Correlations in Alkali Metal Fullerides

[+] Permanent position: Technical University Budapest

Publications

Article

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G. LIQUID CRYSTAL RESEARCH

L. Bata, N. Éber, K. Fodor-Csorba, A. Jákli, A. Vajda

Continuing the study on ferroelectric liquid crystals we observed an increase of the sample thickness up to 0.3μm in a few minutes induced by ac fields which switches the director uniformly and fully. Calculations based on a continuum theory indicates that the effect is due to the increase of the pressure during the switching process. According to the literature this is the first succesful attempt to produce thin films containing ferroelectric liquid crystal where the surface anchoring is so weak that the relaxed texture is helical even at the surfaces. In such films the effective memory angle can be continuously tuned offering a gray scale. Uniformly tilted smectic layer structure in SmC* films on homeotropically treated plates were observed. The layer tilt increases from zero to 14° as the sample is cooled from the smectic A to room temperature. The layer tilt is mainly due to the balance between the surface tension (that prefers horizontal layers) and the homeotropic surfactant (that promotes the director to be normal to the plates).

Studying cholesteric liquid crystals in which small amount of polymer is dispersed a dramatic change of the phase behaviour was observed. Incorporation of 3% of polymer suppresses the melting by 60K and induces a cholesteric glass. The study into the details of this behaviour is on progress.

Liquid crystals containing chlorine atom on the chiral center were synthesized. The liquid crystalline members of the homologous series of (R)-(2-chloropropyl)-4-(4'-n-alkoxy) benzoyloxy benzoates exhibited smectic A phase. We used the n=9 members of the homologous series as a chiral dopant in ferroelectric mixtures. The physical parameters were studied.

^{2}H NMR studies were carried out on the deuterium labelled liquid crystal 4-(2'-methyl-butyl)phenyl4'-n'heptylbiphenyl-4-carboxilate-d18 (7BEF5-d18). The six possibly different aromatic deuterons give rise to two doublets with integral ratio 1.5. This indicates that the para axes of the aromatic rings are substantially parallel to each other. We find three well distinct doublets (corresponding to the three types alkyl deuterons) in the nematic and smectic A phases. In the highly ordered SmB and SmG phases the two methylene groups are locked in the all trans conformation.

Proceedings of the 15th International Liquid Crystal Conference were edited and published as five volumes (260-264) of the Molecular Crystals and Liquid Crystals.

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Grants

OTKA T016252 Liquid Crystal Research
OTKA T 7409 Physical Investigation of liquid crystal - polymer composites

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See also H16, L1, L4, L5, L10

H. INSTABILITIES AND NONLINEAR PHENOMENA IN LIQUID CRYSTALS

Á. Buka, T. Börzsönyi, I. Jánossy, T. Kósa, T. Tóth Katona

Pattern forming instabilities

1. A new experiment was constructed for studying **shear induced instabilities** in nematic liquid crystals. The linear, oscillatory vibration, realised by connecting the membrane of a loudspeaker to one of the confining plates of the cell, is used for generating the transition between the spatially homogeneous and periodic states. A precise measuring system is built for detecting the vibration amplitude and acceleration in all three perpendicular directions. The transitions are detected in a polarising microscope and recorded with a CCD camera. Preliminary measurements are being carried out to describe the temporal behaviour and spatial distribution of the director subject to shear of different amplitude and frequency.

2. The study of **interfacial patterns** has been continued. The thermally driven instability on the nematic-smectic phase boundary was investigated on substances with different molecular structure, on a homologous series as well as on binary mixtures. The homologues, having similar molecular and material parameters show different surface tension anisotropy and this parameter alone causes a large difference in the growth morphology.

   A new co-operation with a theoretical group in Spain proved to be very fruitful. Phase field simulations of the non equilibrium growth of our liquid crystals produce strikingly similar morphologies to the experimental ones. The effect of the surface tension anisotropy is also verified.

3. **Electrically driven instabilities** in homeotropic nematics are also investigated. A fully computer driven system was built to study the creation and motion of defects under the influence of an additional magnetic field. Travelling waves are studied in planar cells and the Hopf frequency is measured as a function of the conductivity, cell thickness and driving frequency.

Non-linear optics. — The investigation of the influence of different dyes on the optical reorientation of nematics has been continued. Studies were carried out on the wavelength dependence of the amplification factor of different dyes and in the case of a diazo dye the change of sign of the effective optical torque with wavelength was discovered. The result was interpreted assuming a fast relaxation process of the vibrational modes in the excited state. The host dependence of the dye-induced optical torque was also demonstrated.

Optical data storage

1. **Cholesterics** of a helical structure doped with a small amount of dye, in order to make them light sensitive, were used to demonstrate that laser illumination can cause a transition from the planar structure to the multidomain focal conics and vice versa. This is one possible way of storing and retrieving information optically.

2. The optical properties of a liquid crystal can also be altered by imposing different boundary conditions. Traditional, mechanical methods result in permanent alignment, contrary to optical techniques, which offer **a non-contact alignment method**, high spatial and angular resolution in the director configuration at the

surface. Azo dye-polyimid guest-host systems were investigated as light sensitive alignment layers. The possibility of laser writing with very high resolution (600 dpi and higher) full grey scale (8-bit grey scale depth) images has been demonstrated. Binary phase optical elements were fabricated using the laser alignment technique and the performance of these devices was analysed.

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OTKA 2976 Spatio-temporal patterns
OTKA T014957 Structure formation in non equilibrium, complex systems
Volkswagen Foundation (German-Hungarian bilateral), Pattern formation in liquid crystals
OTKA 2948 Non-linear optics
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I. METAL PHYSICS

K. Tompa, I. Bakonyi, M. Bokor, Cs. Hargitai, Gy. Lasanda, T. Marek, J. Tóth, E. Tóth-Kádár

Amorphous alloy - hydrogen systems. — The study of metal-hydrogen systems has both intellectual and practical importance. This is the reason why proton NMR spectroscopy (PMR), electric transport measurements, X-ray diffraction and UPS were used in the investigation of these systems.

PMR line shift, spectrum width, hydrogen content, spin-lattice and spin-spin relaxation times, electrical resistivity, UPS spectra and bulk susceptibility were measured on binary Zr-Ni and ternary Zr-Ni-Cu amorphous alloys charged with hydrogen. The temperature interval in which the measurements were done covers the range from liquid helium to about 350 K.

Zr-Ni-(Cu) alloys were prepared by melt spinning from 3N(Zr) 4N (Ni) and 5N (Cu) purity metals after electron beam melting , the non-crystalline state was checked by X-ray diffraction The samples were charged with hydrogen from the gas phase at 30 MPa pressure at ambient temperature.

The main results are the following: The simultaneous measurements of line-shift and bulk susceptibility help to separate the Knight-shift and the chemical shift contributions of the proton line-shift and to understand the electron environment of protons in metals. On the basis of spin-spin relaxation mechanism existing in the high temperature range and from the temperature dependence of the electrical resistivity, the activation energy and correlation time of hydrogen diffusion could be investigated as the function of hydrogen and the third component (Cu) content: both influence the correlation time and not the activation energy contrary to the generally used models. The UPS spectra of ternary systems show Cu-, Ni-, and Zr derived states both before and after hydrogenation. It is found that hydrogen had the greatest effect in the region of Cu-derived states. The effect was ascribed to a hydrogen induced phase separation.

Transition metal complexes. — In the study of transition metal complexes, ^{1}H NMR spectra and spin-lattice relaxation times (T_1) were measured in $[Zn(ptz)_6](BF_4)_2$ (ptz = 1-*n*-propyl-1H-tetrazole) and in the spin-crossover complex $[Fe(ptz)_6](BF_4)_2$ between room temperature and 2.2 K on polycrystalline samples. In the zinc complex, three different types of intramolecular motion of the propyl group were suggested (tunnelling and classical rotation of methyl groups, rotation of methylene groups). These processes can be characterised by $6\cdot10^{-10}$ s, $2.1\cdot10^{-10}$ s, $2.85\cdot10^{-13}$ s correlation times; and 170 J mol^{-1}, 1100 J mol^{-1}, 5100 J mol^{-1} activation energies, respectively. The same quantities to the $–CH_2–CH_3$ reorientation over a three-well asymmetrical potential are $3\cdot10^{-13}$ s and 17000 J mol^{-1}. For the iron complex the same dynamics was found, which was expected because of the isomorphic structure of the two complex. In addition, clear signs of presence of high-spin state Fe^{2+} ions were detected. From the T_1 values the high-spin fraction ($\gamma_{HS}(T)$) was calculated. The result shows that some Fe^{2+} ions remained in the high-spin state even at the lowest temperatures. The temperature of the spin-crossover (where $\gamma_{HS} = 0.5$) was found to be ~135 K according to the line shape measurements and ~137 K according to the T_1 measurements. The mechanism of the paramagnetic relaxation was found to be of rapid diffusion type according to the theory of Lowe and Tse ($\tau_0 = 1.0\cdot10^{-13}$ s, E = 3000 J mol^{-1}).

Nanocrystalline metals — Previous work on electrodeposited nanocrystalline (nc) Ni foils was continued and was extended also to Co metal. The results on the low-temperature electrical resistivity on pulse-plated nc Ni samples showed a systematic increase of the residual resistivity with decreasing grain size. Pulse-reversal (PR) plated nc Ni samples were also produced by using cathodic pulses of fixed amplitude i_c and length t_c and by varying the amplitude (i_a) and length (t_a) of anodic pulses. A direct observation of the microstructure of these PR Ni foils has not yet been performed but it can be ascertained, based on the electrical transport data, that these foils also exhibit a nanocrystalline structure. These data suggested that the PR-plating method can be very effective in reducing the grain size. The TEM study of a DC-plated Co foil revealed a fine and uniform grain structure, the average grain size being about 30 nm. The temperature dependence of the electrical resistivity indicated the presence of a large residual resistivity contribution in nc Co due to the small crystallite size.

Metallic multilayers — A sulfate bath was used to produce typically 5 μm thick electrodeposited Ni-Cu/Cu multilayer foils with up to several thousand repeats. After removing the Ti substrate, the room-temperature magnetoresistance of these self-supporting multilayers was studied as a function of the ferromagnetic Ni-Cu layer thickness. Giant magnetoresistance was observed which peaked at about 2 % for Ni-Cu layer thicknesses around 2 to 3 nm.

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Grants

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OTKA T015649 Giant magnetotransport phenomena in nanophase metals
OTKA T016670 NMR relaxation and local properties in solids
OMFB-British Council Joint project No. 15: Electrodeposited thin films
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See also J3, J4, J6, J9, J10, J11, O11.

J. METALLURGY AND MAGNETISM

A. Lovas, J. Garaguly, P. Kamasa, G. Konczos, L. Pogány, T. Tarnóczi, I. Varga, L.K. Varga

Hydrogen absorption and desorption processes in glassy alloys. — The time evolution of hydrogen charging and discharging in Ni-Zr glassy alloys has been studied by in-situ resisitivity measurements in order to clarify the details of the activation. The resistivity increase caused by the hydrogen uptake has been used for separating the surface and bulk processes. Hydrogen was introduced into the samples from the gas phase by using a high-pressure chamber in which the sample holder, the samples and the electrical contacts are placed. Using this method, a reversible and an irreversible part of the resistivity change were detected during the cyclic charging and discharging process. The ratio of the reversible and irreversible change was found to depend on the Zr-content.

The mechanism of the H-uptake in H_2 atmosphere and in galvanic doping was compared by using in-situ resistivity measurements. Simultaneously, the maximum hydrogen storage capacity in the amorphous $Ni_{1-x}Zr_x$ alloys was determined. Electrochemical measurements have also been performed on these alloys in order to characterize their behaviour with regard to their potential applications as metal hydride battery electrode materials.

Study of nanocrystalline soft-magnetic alloys. — We have continued the systematic study of soft magnetic properties of nanocrystalline materials obtained from amorphous precursors. Beside the Fe-B-Si-Cu-Nb based (Finemet type) alloys we have investigated the Fe-Zr-B based alloys, too. In both types of materials the nature and volume fraction of the structural phases are subject of great controversy in the literature.

Therefore, we have carried out detailed thermomagnetic measurements on partially crystallized samples. The evolution of the Curie temperature as a function of annealing time and temperature was attributed to the change of the chemical composition of the particular phase provided that the given phase does not decomposes completely during the thermomagnetic measurements.

We have shown for both types of materials that instead of stable phases a supersaturated metastable, bcc phase appears in the first stage of crystallization (with the early transition element dissolved in the bcc phase) which is responsible for the T_c suppression of the bcc phase and this metastable phase transforms only at the second stage of crystallization by precipitation of the solute elements indicated by the steep increase of T_c.

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Grants

OTKA T4219 Role of exchange interaction in the relaxation of metallic glasses

OTKA 1975 Formation of disordered, non-equilibrium structures (cooperation with the A. József University, Szeged)

OTKA T7506 Study of new phenomena and properties in the plasma spraying of Al_2O_3 and Al base powders made by mechanical alloying (cooperation with the Technical University Budapest)

OMFB[3] 94-97-69-0660 Development of conductive polymer composites (cooperation with the Plastic Research and Development Ltd., Budapest).

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AEKI[4]: Contract for materials research by SEM

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[4]AEKI: Research Institute for Atomic Energy

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See also D.9, I.8, I.9, I.10, I.11, I.12, I.14

K. NON-DESTRUCTIVE EVALUATION

F. Tóth

Remote field eddy current inspection technique and instrument for testing thick ferromagnetic tubes. - The conventional eddy current non-destructive testing has been successfully applied for the in-service inspection of non-magnetic tubes. However, the attempt of applying it to the inspection of thick magnetic tubes has not succeeded because the high permeability causes small skin depth for eddy currents.

Lots of magnetic tubes and vessels used in the petrochemical industry and power plants have remained uninspected because there has been no proper in-service test method for inspecting their condition at a reasonable inspection speed.

The remote field eddy current technique has advantages over standard eddy current techniques in that it inspects both ferrous and non-ferrous materials with equal sensitivity to internal or external anomalies.

This technique, unlike more conventional eddy current testing, places detector arrays in the remote field region: the distance between exciter and detector coils being about two to three tube diameters.

At this spacing the direct coupling between exciter and detector coils is insignificant. The energy transmitted inside the tube is very strongly attenuated. The dominant coupling occurs through an indirect energy flow path. Fields from the exciter coil diffuse out through the tube wall in the vicinity of the exciter, being attenuated and phase shifted under eddy current skin depth behaviour in the process. These fields propagate with moderate attenuation to the outside until, in the remote field region, the external field is greater than the internal field. The dominant internal field is then due to energy diffusing back inwards through the tube wall, again being phase shifted and attenuated in the process. Anomalies occuring anywhere in this energy flow path, cause anomalies in the detector signal. Phase lag of the detector signals with respect to the exciter is commonly used as the measure of pipe characteristics, such as wall thickness. Complex plane representation may also be used, as in conventional eddy current techniques, to facilitate defect classification.

The developed instrument (Ferrotester) and probes can detect boiler, condenser tube and pipe thinning, erosion, corrosion, areas with cracks, wears, etc. It is tested in a thermal power plant (Százhalombatta).

Grants

OMFB No. 94-97-47-0698 Micromagnetic non-destructive testing equipment for measuring internal stresses and fatigue

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L. NEUTRON SCATTERING IN CONDENSED MATTER

L. Rosta, S. Borbély, L. Cser, B. Faragó[+], T. Grósz, J. Jani, P. Jóvári, Gy. Káli, L. Kõszegi, F. Mezei[++], L. Riecsánszky, Gy. Török

The neutron scattering research activity is performed essentially at the 10 MW Budapest Research Reactor (BRR). With its 10^{14} neutrons/cm^{2}s core flux, optimised neutron beam take off systems, 35 weeks of yearly operation this unique neutron source in Central-Europe provides excellent opportunities for neutron beam research. Due to some of their unique features in scattering experiments, neutrons are useful tools for the investigation of structural and dynamical properties of condensed matter.

The following instruments are used or being installed:

- **A three-axis spectrometer** on the curved neutron guide position NG1/1 with its sophisticated monochromator shielding (thus extremely low background) provides measuring opportunities in the low energy transfer range, as well as for high resolution diffraction or diffuse scattering. A velocity selector for the harmonic filtering of the monochromatic beam makes it unique in providing continuously variable filtered incident wavelength.
- **A small angle neutron scattering spectrometer (SANS)** on the curved neutron guide NG2, with an XY-detector and flexibly variable parameters, is the type of instrument most highly demanded for various problems of medium range structural behaviour of liquid type and soft matters, alloys, composites, etc.
- **The construction of a material test diffractometer** is finished and it is ready to be installed during 1996 on a thermal beam tube. Its essential part is a 4-circle goniometer transferred to BRR from Harwell. It will be optimised for strain analysis and texture measurements.

Besides the above activity on the development of neutron scattering spectrometers considerable efforts have been made on the improvement of the experimental infrastructure, e.g. a 15m section of neutron guide has been installed (now this guide beam is available for new instruments). By improving the neutron guide and the instrument shieldings, the biological irradiation background level has been reduced far below the permissible limit in the guide hall. The sample environment has been developed: low temperature (77K) facility and magnetic field (up to 1.5T) are available on the SANS instrument.

The preparation of Technical Documentation of the liquid hydrogen Cold Neutron Source including the Technical Design and Safety Analysis was started in collaboration with the Gatchina Neutron Physics Institute (Russia) development team financed by the technical assistance grant of IAEA and with project managing provided by the Project Agency ETV-ERÕTERV acting as General Designer on behalf of the Budapest Neutron Centre.

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Our condensed matter investigations were focused mainly on the following topics:

Soft matters and liquid based systems. — Mixed surfactant solutions: Sodium dodecyl sulphate (SDS)-decanol and hexadecyl trimethylammonium bromide - 3-methylsalicilic acid were studied by small-angle scattering. At 10:1 and 5:1 SDS-to-decanol molar ratio mixed micelles are formed in the solution, but at 2:1 molar ratio various liquid crystalline phases were observed depending on the concentration and temperature. Increasing the amount of 3-methylsalicilic acid added to CTAB induces the growing of giant polymer-like aggregates that could be described by the formalism worked out in polymer physics.

Hydrofobic interaction: High resolution structure factor of the tetramethylurea (TMU) water solution was investigated. The use of the contrast variation allows to reconstruct the partial pair correlation functions characterising the relative distribution of the TMU molecules.

Gels: Silica and aluminium type inorganic gels were investigated. Fractal exponents determined from the measurements gave values corresponding the co-ordination numbers of the agglomerations that varies between 1.5 and 2.6 depending on the state of the gelation. Strong anisotropy appears when the gelation process is accelerated by gradient heating. From the lower part of the transferred momentum range the correlation length of the agglomerations was evaluated. (The study was done in the frame of the collaboration with the Chemical Dept. of the Eötvös Loránd University, Budapest.)

The so called supergels (with swelling ability up to 1500) were measured with small angle neutron scattering combined with the contrast variation method. It was demonstrated that the contribution to the scattering intensity from the polyionic chains can be distinguished from the network stabilising cellulose knots.

Composite materials based on liquid crystals are important for industrial application. The structural aspects - with units of nanometer sizes - can be well studied by small angle neutron scattering. We have shown that in a liquid crystal (LC) dispersed polymer system the macroscopic LC anisotropy can be stabilised even when the orienting field is switched off. This was explained by the interaction of the LC matrix and the rough surface of the polymer fibrils. In contrast, recent measurements on a system where a few nanometer size globular silicide particles are dispersed in a LC matrix, reveal that particle aggregation seems to hinder orientation of the liquid crystal by external field.

Ferrofluids - suspension of ferromagnetic particles - are widely used in various fields of industry and medicine. The structural and diffusion behaviour of ferrofluids are governed by the balance of magnetic, dipole and molecular interactions. The particle aggregation processes can be studied in details as a function of the solvent concentration, external magnetic field and temperature by SANS and neutron spin echo. An experiment performed on the NSE spectrometer at LLB-Saclay, partly operated by our institute, revealed that in the low T_c $Zn_{0.3}Mn_{0.7}Fe_2O_4$-based sample ~100Å diameter particles are dynamically associated to form fractal-type aggregates.

Metals and alloys. — Complex (SANS, strain analysis, texture investigation and optical observations) structural investigation of Al-based composite materials was carried out aiming to determine the correlation between structural and mechanical properties. It was proven that the strengthening fibres (Si-carbide) form textures. Mechanical weakening of the material is caused by the texture change.

We have continued - in collaboration with the University of Vienna - the investigation of the decomposition in binary alloys. While in the Au-Pt system decomposition leads to the formation of a parallel platelet-type structure with long range ordering, in the case of Cu-Rh alloys the balance of lattice misfit and surface tension effects yields a three-dimensional symmetric clustering in the cubic directions without long range correlations.

The excess internal stress distribution was measured on porous iron-copper alloy as a function of external stresses. The in situ measurements were performed on a tensile test specimen fitted in a stress rig designed for neutron investigation. Inhomogeneity of the internal stresses corresponds the inhomogeneity of porosity.

The study of embrittlement of steels by irradiation damage has crucial importance in nuclear engineering. In the framework of our collaboration, the Léon Brillouin Laboratory (France) has initiated the study of model nuclear reactor vessel materials. A magnetic anisotropy due to Cu-rich precipitations induced by irradiation has been demonstrated on the SANS spectrometer at BRR.

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Grants

OTKA T 4490	Complex investigation of hydrophobic effects in aqueous solutions
OTKA T 16943	Decomposition of liquid crystal based binary systems
OTKA T 17016	Ordering phenomena in interface and surface thin layers
EU Network: WENNET	Neutron scattering in molecular systems
EU PECO	Use of neutron source facilities at LLB Saclay

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L.13. L. Cser: Future prospects of the Budapest Neutron Centre (Science and instrumentation) Ibid., C8

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L.24. V.T. Lebedev*, G.P. Gordeev*, V.G. Veselago*, G.A. Evmenenko*, A.I. Sibilev*, V.V. Kljubin*, A.L. Kachurin*, V.N. Zabenkin*, L.Cser, L.Rosta, Gy.Török: Small Angle Neutron Scattering from Low-T_C ferrofluid. Russian Academy of Sciences Petersburg Nuclear Physics Institute, preprint 2027.

See also D7, G2

M. INTERACTIONS OF INTENSE LASER FIELDS WITH MATTER

Gy. Farkas, A. Kõházi-Kis, Cs. Tóth, S. Varró

High order laser-harmonic generation in the GW/cm^2-TW/cm^2 non-perturbative intensity range. — When a metal surface is illuminated by a sufficiently strong laser pulse, coherent light beams at the multiples of the laser frequences ("high laser harmonics") appear in the specularly reflected direction. The high harmonic generation from a metal surface was realised in the transition region between the perturbative and the non-perturbative regimes. While 3 μm long wavelength free electron laser pulses of GW/cm^2 and psec duration did not produce harmonics, strong second and third harmonics were detected when the subpicosecond duration laser pulses of TW/cm^2 were applied at 2 μm wavelength. In both cases strong electron emission also appeared. The intensity dependences both of the harmonic and electron emission yields showed strongly non-perturbative character, as predicted by the QED.

Intense harmonic generation was observed also with femtosec duration (i.e. broad spectral band) pulses of a Ti:Sapphire laser around 0.8 μm, exhibiting a strong dispersion (i.e., decrease with increasing wavelength) of the harmonic yield. The obtained new phenomena may be interpreted on the base of renewed QED theories based on the non-perturbative calculations taking into account the collective "jellium model" of the metallic electrons.

Theories describing the laser induced interactions of the electrons of atoms and solids. — We have developed new theories to predict observable phenomena and to interpret experimentally observed new results, respectively. The most important ones are: the "cut-off" rule of the highest observable harmonics at a given metal for the laser intensity used; the anomalous perturbation-order laser intensity dependence and anomalously high experimental yield both of the harmonics and the multiphoton (tunnel) electron emission, respectively. Other QED theories developed by us predict very sensitive dependences on the bichromaticy, the relative phases and the polarisation of the inducing laser fields in different interaction processes with both single particle-type and collective atomic systems.

New theoretical proposals for GeV laser accelerators for free electrons and TW/cm^2 intensity X-ray beam production. — Based on our former fundamental observation for multiphoton scattering of laser photons by free electrons, we renewed and elaborated a fundamental theory for the multiphoton Compton scattering for the case of the recently available extreme high (~10^{19} W/cm^2) laser intensities. This theory revealed that at these intensities with the use of "table top" laser accelerators *GeV electron energies* may be achieved, which fact may break the limits of the recent traditional accelerators. At the same time, the laser photons, scattered forward from accelerated fast electrons furnish *TW/cm^2 soft (~KeV) coherent X-ray beams.*

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Grants

OTKA I/3 2936 Experimental investigation of interactions predicted by high intensity QED

OTKA I/4 4471 Electron emission processes induced by the simultaneous presence of two intense laser fields of various frequencies

OTKA I/7 T16014 Experimental and theoretical investigation of new fundamental physical processes (laser-matter interactions) induced by laser beams of superintense (10^{15} - 10^{20} W/cm^2) laser systems.

BALATON 25/94 (French-Hungarian Bilateral Cooperation): Picosecond time scale caracterisation of light beams of higher order harmonics generated by intenese laser beams at metal surfaces

BALATON 6/95 High harmonic generation in the interaction of laser pulses with surfaces: the investigation of the phenomenon in the infrared at high laser intensities.

NATO Linkage Grant #930179 (USA-Hungary): Interaction studies of ultra intense laser fields with matters

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M.10. T. Dennis*, H.M. Duiker*, J.Wu*, Cs. Tóth, J.F. Young*: Comparison of laser produced plasma target materials for pumping the 109 nm Xe^{2+} Auger laser. To be published in IEEE J. Quantum Electronics

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M.14. Gy. Farkas, A. Kõházi, Cs. Tóth, F. Heisel*, J.A. Miehé*: Time resolved characterization of various order harmonic generation at metal surfaces: Streak camera and autocorrelation studies. To be published in Applied Physics B

N. LASER PHYSICS

M. Jánossy, P. Apai, T. Bereczki, L. Csillag, Z. Donkó, Á. Hoffmann, Z. Horváth, Zs. Lenkefi, P. Mezei, K. Rózsa, L. Szalai, K. Szõcs, Zs. Szentirmay

Lasers in segmented hollow cathode discharges. — The segmented hollow cathode discharge recently developed for excitation of continuous UV lasers proved to be the most efficient one among hollow cathode discharges applied for laser purposes. These lasers are excited via charge and energy transfer between ground state noble gas ions and metal atoms. The hollow cathode discharge fits the excitation mechanism. High density of ions are produced by the fast electrons while the proper metal vapour density can be ensured by cathode sputtering. The novel discharge geometry combines the advantages of the conventional and the increased voltage hollow cathode discharges. It ensures the oscillations of the fast electrons which are focused into the cavity by the cathode geometry. Thus high density of fast electrons can be produced. The energetic ion bombardment helps for the cathode sputtering. The discharge is highly stable against arcing, due to the positive slope of the voltage current characteristic. On the copper 270 nm transitions we found 6.5 A threshold current, and 18%/m gain. The most efficient excitation can be reached at 150 - 200 mA/cm linear current density. We have performed spectroscopic investigations on the VUV spectrum of the segmented hollow cathode discharge. Our results indicate that for the possible continuous laser oscillation around 160 nm on the Cu II transitions, the segmented hollow cathode discharge are favourable compared to the conventional hollow cathode discharges.

Gas discharge physics. — We have investigated the effect of the reflection of electrons from the anode in obstructed glow discharges. Our computer simulations of the electrons' motion in the discharge have shown, that (in the obstructed mode) a high number of fast electrons reach the anode, and if reflected, they produce a significant amount of additional ionization. The effect of electrode reflection was experimentally proven by constructing two discharges with different electrode material. We have also studied the energy distribution of positive ions in a helium-neon mixture glow discharge and have carried out spatially resolved measurements of copper concentration in a sputtering copper hollow cathode discharge in argon gas (using the method of spectral interferometry). We have started to develop a model of the segmented hollow cathode discharge which is an efficient pumping source for metal ion UV lasers. Nonlinear behaviour of discharges was also part of our studies. We have used computer simulation to study the statistics of electron avalanches and bursts (sequence of avalanches) below the breakdown voltage of the discharge. In a self-oscillating subnormal glow discharge we have observed the period doubling route to chaos as an effect of periodic perturbation of the discharge.

Electrolyte cathode atmospheric glow discharge. — The cathode fall, the current density and the emission intensity of neutral atoms contained in the electrolyte were investigated as a function of the discharge parameters in order to determine an operating modell of the solution - plasma interface. The cathode fall was found to be constant in the pressure range of 266 -961 mbar in accordance with the literature. The decreasing cathode fall with the decreasing pH was attributed to an increase of the secondary electron emission coefficient. The dependence of the current density on the pressure (that violates the similarity laws) was in accordance with the earlier data, this gave a possibility to use them in developing of our modell. In this operating modell of

the solution - plasma interface, the increase of the secondary electron emission coefficient with decreasing pH is explained by participation of photons and solvated electrons in the secondary electron emission of electrolyte cathode. the efficiency of the secondary electron emission is linearly effected by the proton activity of the electrolyte cathode through a reaction that developed on the base of the radiation chemistry of solutions.

Research on multidimensional lasers. — The research of multidimensional lasers, the production of "non-line-like" coherent light, stimulates a growing interest, as relatively large laser active volumes can be handled in relatively small geometrical sizes, using the multidimensional concept, in contrast to the usual cylinder or tube shaped geometries. The absence of classical laser resonators suggests the appearance of the same phenomena in case of natural, cosmic- or biological laser processes. The unusual geometries of the laser active materials show special fluorescence distribution properties of the experimental samples. In the present state of our research work we developed special fluorescence imaging systems to study the phenomena. This technology can also be successfully used in the medical photodynamic cancer diagnostics, in forensic sciences to examine documents or body fluids, in agro technology and pharmaceutical production to control the distribution of different chemical components or in the environmental protection for early detection of vegetation stress. Several experimental results, achieved in strong cooperation with the specialists of the corresponding fields, successfully demonstrated the practical importance of the above modern optical tools.

ATR study of noble metal films. — An ATR (attenuated total reflection) reflectometer was constructed using a twin goniometer system and lock-in detection technique. The angular resolution was 0.015 deg., determined by the beam divergence of the He-Ne and YAG laser light sources, while the error in reflectivity was less than 2%. The angular distribution of the ATR reflectivity and backward resonance light emission was measured in evaporated silver and gold films of 30-90 nm thickness with both wavelengths (0.6382 nm and 1.064 nm). Exact roughness spectrums were determined by a fitting procedure using the Kröger-Kretschmann formulae. A relatively sharp thickness dependence was found in the components of the dielectric constant at both wavelengths.

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Grants:

OTKA T014909	Lasers in hollow cathode discharges
OTKA F7475	Chaotic phenomena in gas discharges
OTKA F015502	Basic processes of glow discharges in the cathode region

OTKA T014850	Electrolyte cathode atmospheric glow discharge
OTKA T4220	Multidimensional lasers
OMFB 04076-94-01-10	Fluorescence imaging
OTKA T017293	Multidimensional lasers
OTKA T016075	Surface plasmon studies
OTKA T4227	Excitation mechanisms in hollow cathode lasers

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production of an atmospheric molecular force acting on a solid without thermal gradient, in Hungarian). Patent submitted to OTH[5] No P 95 00280 (1995)

[5]OTH: National Patent Bureau

O. LASER APPLICATION

I. Kertész, A. Czitrovszky, P. Jani, Á. Kiss, M. Koós, Gy. Messing, Said H.S. Moustafa, B. Plósz, I. Pócsik

Solid state laser development: Different wavelength devices were built on the base of previously developed mechanical-, power supply-modules and Er:YAG, Nd:GGG, Er-glass active materials for medical purposes.

Our novel, piezo driven Fabry-Perot Q-switch was checked up to 2-2,5 kW average power with an Euro Laser of the EU-226 project. The Q-switch worked manually and automatically on any frequency in the 1-100 KHz range delivering 50-300 ns long pulses of 0,1-1 MW peak power. The effect of the Q-switched output was compared with the results achieved by continuous lasers. The average power threshold for welding was measured to be about two times lower in the frame of the Brite Euram-7997 project. The quality of welding naturally decreased but in the case of drilling, cutting etc. the processing parameters were better for the Q-switched than those for the continuous mode of laser operation. Improvement of the beam quality was observed up to 300-500 watt average output power but at higher amplification rates the direction dependent Fabry-Perot reflectivity was not enough high to have a significant influence on the beam distribution.

In the case of medium power (for example medical) lasers the beam quality improvement of the Fabry-Perot output mirror made the use of much thinner optical fibbers possible that is the beam delivery became more flexible.

Optical measuring techniques based on light scattering and interference. — On the basis of previously developed APC-03-2 and APC-03-2A airborne particle counters, in collaboration with the Environmental Health Department of the Municipal Institute of State Public Health Service (ÁNTSZFI) several methods were applied to study the airborne dust particle pollution within the city of Budapest at various locations and during different seasons of the year. In these measurements we compared the results of 3 different methods and found a good agreement among the measured results. The determination of the size distribution and time dependence of airborne dust particles at various locations, which was applied in air quality monitoring network of Budapest for the first time, opens new possibilities for environmental control. The results of complex measurements demonstrate that in certain cases the measured pollution level exceeded the values permitted by health standards.

The size distribution and concentration of the liquid-borne particles was determined in various pharmaceutical products using the liquid-borne particle counter LQB-1-200 developed by our group.

Further optimizations of the optical system and improvement of the electronics was carried out in the system developed for generation of squeezed light by non-collinear parametrical down conversion.

Amorphous thin layers. — Current project: "Diamond-like" hydrogenated amorphous carbon (a-C:H). Thin films of this material exhibit a number of attractive technological properties, similar to those of diamond. These include transparency in the infra-red/visible region, low dielectric constant, hardness, low coefficient of friction and chemical inertness. In addition, as a coating material, it has some advantages over polycrystalline diamond films, because they can be deposited on large

substrates held at low temperature with an ultra-smooth surface finish. Another interesting property of diamond-like a-C:H is that its optical properties can be changed over a wide range. Modelling the electronic structure of a-C:H, it was suggested that both valence- and conduction-band edges are formed from π states on sp^2 sites which are clustered. These clusters are interconnected by sp^3 carbon. However, research carried out in this field in the last few years has pointed to more subtle relationship between nanostructure and macroscopic properties than it was originally thought.

The intriguing question of structural arrangement of sp^2 sites, whether graphitic clusters or polymeric chains are embedded in sp^3 bonded matrix, was placed into the focus of our research. For this reason, bonding characteristics e.g. sp^3/sp^2 ratio and hydrogen content of a-C:H films were varied in a wide range. Nuclear magnetic resonance and FT Raman measurements were carried out for structural characterization of samples, while electronic properties, tail states, and localised levels were studied by optical and electrical methods.

Because of resonance, an improved resolution in Raman spectra allowed detection of fine structure of a-C:H spectra. Computer decomposition shows two new broad band; one of which (~1200 cm^{-1}) was theoreticlly predicted for purely tetrahedally bonded carbon without long range order, and the other (~1460 cm^{-1}) can be assigned to linear polymer chains including C=C bonds. At the same time, scattering bands due to graphitic clusters were also observed.

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Grants:

ACCORD 9112-0167:	Beam quality control and improvement of high power solid state lasers
OTKA 1444	Generation of squeezed light and studying of their properties
OTKA T 4223	Cluster size distribution in amorphous carbon films and their effect on the physical properties of the films
OTKA T017371	"Diamond-like" amorphous carbon: atomic bonds, nanostructure and macroscopic properties

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Articles

O.1. A. Czitrovszky, P. Jani: Application examples of APC-03-2 and APC-03-2A Airborne Particle Counters in a highly contaminated environment, Journal of Aerosol Science, **26**, 793-794 (1995)

O.2. P. Jani, A. Czitrovszky: Aerosol particle velocity and size measurement by photon correlation. Journal of Aerosol Science, **26**, 799-800 (1995)

O.3. A. Czitrovszky, T. Mosoni*, P. Jani: Calibration and application examples of the LPC-1-200 Liquidborne Particle Counter, Journal of Aerosol Science, **26**, 791-792 (1995)

O.4. M. Koós, S.H. Moustafa, I. Pócsik: 1/f noise in hydrogenated amorphous carbon layers. In: *Noise in Physical Systems and 1/f Fluctuations,* V. Bareikis and R. Katilius (eds.), World Scientific, Singapore 1995, pp. 311-314

O.5. I. Pócsik, M. Koós: Coloured noise, inhomogeneous conductivity and fractal feature in amorphous matter. In *ibid.*, pp. 272-275

O.6. A. Czitrovszky, J. Frecska*, P. Jani, L. Matus*, A. Nagy: Formation, size distribution and concentration of aerosols released from heated LWR fuel rods. To be published in Aerosol Science and Technology.

O.7. A. Czitrovszky, P. Csonka, P. Jani, Á. Ringelhann*, J. Bobvos*: Complex measurement of dust pollution within the city of Budapest. To be published in Environmental Pollution

O.8. A. Czitrovszky, P. Csonka, P. Jani, Á. Ringelhann*, J. Bobvos*: Comparison of tree measurement methods of airborne dust pollution within the city of Budapest. To be published in Environment International.

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O.10. I. Pócsik, M. Koós: Spectral inhomogeneity - a key issue for understanding relaxation in amorphous matter. To be published in J. Non-Cryst. Solids

O.11. I. Pócsik, M. Koós, S.H. Moustafa, Gy. Lassanda, P. Bánki, K. Tompa: Temperature ependence of 1H NMR relaxation in hydrogenated amorphous carbon sample series To be published in J. Non-Cryst. Solids

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O.12. Yu. Danileiko*, B. Denker*, I. Kertész, N. Kroó, V. Osiko*, A. Prokhorov*, S. Sverchkov*: Piezoelectric driven devices for periodical Q-switching of high average power lasers. *Proc. Laser 95 Congress, München, 1995,* K103

O.13. I. Kertész, N. Kroó, Yu. Danileiko*, B. Denker*, A. Korchagiu*, V. Osiko*, A. Prokhorov*: Optoelectronic element for the control of the spatial and time behaviour of medical lasers. *Proc. Env. Biomedical Week, Barcelona, 1995,* pp. 2629-53

Others

O.14. I. Kertész: Beam quality control and improvement of high power solid state lasers. Final report on the ACCORD 9112-0167 project (1995)

O.15. A. Czitrovszky, P. Jani, N. Kroó, Airborne particle counter for determination of the size distribution and concentration of the particles. Hungarian patent No 209881.

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P. OPTICAL THIN FILMS

K. Ferencz, R. Szipöcs

Optical thin film structures in femtosecond laser systems. — Femtosecond laser systems contain optical coatings as important functional elements, for instance high reflectors, output couplers, antireflection coatings, beamsplitters and thin film polarizers. System performance strongly depends on the quality of such coatings: reflectances of HRs should approach the ideal 100% value over the entire operation range in order to decrease losses; input couplers should have nearly 100% transmittance at the pump wavelength(s); the output coupling of OCs should be set to a specific value - usually over a broad spectral range - to ensure optimum operation. In some applications, a continuous reflectance (or transmittance) versus wavelength function is desirable, e.g. in femtosecond solid-state laser amplifiers to compensate the gain narrowing effect by spectral filtering of the pulse. Additionally, all the coatings listed above need to be optimized for phase characteristics to prevent the pulse shape from undesirable distortion.

1. **Chirped dielectric mirrors.** Continuing the work started in 1993, our research concentrated on the development of laser optical coatings exhibiting well defined dispersion properties. Previously, we initiated a new technology for dispersion control in femtosecond laser systems: for the first time, we have shown that *chirped dielectric mirrors* may exhibit high reflectivity and nearly constant negative dispersion over frequency ranges of 80 THz around 800 nm. We dare say that our invention has "pushed the limits of femtosecond laser technology": using these special laser mirrors more compact, reliable and user friendly femtosecond laser oscillators, laser amplifiers and optical parametric oscillators can be built than previously.

   Theory of chirped mirrors: Recently, we have shown that dielectric rugate mirrors with pre-set phase and amplitude characteristics can be synthesised by the use of Fourier transform. Now, using this technique, we investigate how the extremely broad bandwidths of chirped laser mirrors can be reconciled with smooth dispersion functions.

   Design of chirped mirrors. The chirped mirrors are designed by the use of our computer software comprising a simple computer refinement algorithm, which minimise the quadratic deviation of the complex reflectivity vs. frequency function of the actual mirror design from the required specification by automatically modifying layer thicknesses. In order to obtain more sophisticated designs, the computer software has been further developed: now it allows us to design chirped mirrors being transparent for the pump wavelength(s), and we can analyse the effect of deposition errors on the dispersion properties of different designs for instance.

   Deposition technology of chirped mirrors. From the technological point of view, chirped structures consisting of different coating materials have been designed, analysed and tested in order to minimize their reflection losses and their sensitivity for deposistion errors.

2. **White light interferometry for dispersion measurement on laser mirrors, laser active materials and other cavity elements.** In cooperation with JATE University of Szeged, two interferometric methods have been developed for dispersion

measurement on laser mirrors: the first technique is fully automated and based on a Michelson interferometer illuminated by a white light source. The interference patterns corresponding to different wavelengths are spectrally dispersed and imaged on a CCD camera. By computer processing of the images, dispersive properties of laser mirrors can be obtained promptly after their deposition with a high accuracy. The other technique uses a Fabry-Perot interferometer arrangement. By determining the spectral position of transmission maxima of the Fabry-Perot interferometer formed by the mirrors to be characterised, the group delay of laser mirrors can be measured with a similar accuracy.

Lately, we have developed a novel interferometric technique for dispersion measurement in bulk optical components such as laser active crystals and optical glasses. The technique has been applied for dispersion measurements in Cr:LISAF, Cr:LICAF and Cr:LISGAF crystals. By using these solid state laser active materials and dispersive dielectric mirrors for dispersion control, we plan building diode-pumped femtosecond laser oscillators with extremely small size parameters in cooperation with our partners at Technische Universitat Wien, Austria (TUW) and ETH Zurich, Switzerland.

3. **Applications of chirped mirrors in femtosecond laser systems.** Chirped dielectric mirrors transparent for the pump wavelengths (488 nm, 514 nm), highly reflective over the 670-930 nm wavelength range and exhibiting negative dispersion over the same spectral range have been used for building a self-mode-locked *Ti:sapphire ring oscillator* at the TUW. The laser generates bandwidth limited 7.5 fs pulses around 800 nm, which represents the best result reported to date.

   A *novel pulse stretching-compression system* suitable for kHz-rate chirped-pulse amplification of 10 to 20 fs pulses has been developed in cooperation with TUW. The compressor consists of a pair of prisms and chiped multilayer dielectric mirrors compensating high order dispersion.

   We have described the operation characteristics of *femtosecond parametric oscillators* employing chirped mirrors for intracavity group-velocity dispersion compensation in cooperation with MPI Stuttgart, Germany. Recently, we adopted the interferometric techniques mentioned above for the wavelength range of 1.1 to 1.4 microns, which resulted in higher quality of chirped mirrors developed for this part of the optical spectrum.

4. **Other developments on optical coatings.** Low loss dielectric mirrors have been developed for a hollow cathode copper laser. The mirrors have been succesfully tested by our colleagues at the Department of Laser Physics (K. Rózsa et. al.). Using our mirrors they could make the laser operate at a wavelength as short as 260 nm.

   Optical waveguides deposited on optical gratings were developed for optical sensors used for medical applications.

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Grant

OTKA T-7376 Optical thin film structures in femtosecond laser systems

Publications

Articles

P.1. A. Stingl*, M. Lenzner*, Ch. Spielmann*, F. Krausz* R. Szipöcs: Sub-10-fs, mirror-dispersion-controlled Ti:sapphire laser. Opt. Lett. **20**, 602-604 (1995)

P.2. A. P. Kovács*, K. Osvay*, Zs. Bor*, R. Szipöcs: Group-delay measurement on laser mirrors by spectrally resolved white-light interferometry. Opt. Lett. **20**, 788-790 (1995)

P.3. J. Hebling*, E. J. Mayer*, J. Kuhl*, R. Szipöcs: Chirped-mirror dispersion-compensated optical parametric oscillator. Opt. Lett. **20**, 919-921 (1995)

P.4. K.Osvay*, G.Kurdi*, J.Hebling*, A.P.Kovács*, Z.Bor*, R. Szipöcs: Measurement of the group delay of laser mirrors by a Fabri-Perot interferometer. Opt. Lett. **20**, 2339-2341 (1995)

P.5. R. Szipöcs, A. Stingl*, Ch. Spielmann*, F. Krausz* : Pushing the limits of femtosecond technology: Chirped dielectric mirrors. Optics & Photonics News **6**, 16-59 (1995)

P.6. Ch. Spielmann*, M. Lenzner*, A. Stingl*, R. Szipöcs, F. Krausz* : Femtosekundenlaser: Sind die Grenzen schon erreicht? (Femtosecond-pulse lasers: Has the limit already been reached?, in German) Phys. Bl. **51**, 289-292 (1995)

P.7. Ch.Spielmann*, M.Lenzner*, F.Krausz*, R.Szipöcs: Compact, high-throughput expansion-compression scheme for chirped pulse amplification in the 10 fs range. Opt. Commun. **120**, 321-324 (1995)

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P.8. Ch. Spielmann*, T. Brabec*, M. Lenzner*, A. Stingl*, R. Szipöcs, F. Krausz* : Advances in ultrafast solid state lasers. In: Proc. of Photonics West 95 Conference (*Generation, Amplification and Measurement of Ultrashort Laser Pulses II)*, San Jose, CA, USA, Eds. F. Wise, C.P.J. Barty, Proc. SPIE 2377, pp. 2-10 (1995)

P.9. R. Szipöcs, A. Stingl*, Ch. Spielmann*, F. Krausz*: Chirped dielectric mirrors for dispersion control in femtosecond laser systems. Ibid. pp. 11-22, (1995)

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P.10. A. Stingl*, M. Lenzner*, Ch. Spielmann*, F. Krausz* R. Szipöcs: Generation of bandwidth-limited 8-fs optical pulses by a mirror-dispersion-controlled Ti:sapphire laser. *Technical Digest of the Conference on Lasers and Electro-*

Optics 1995, Baltimore, MA, USA, Optical Society of America, Washington, D.C., paper CWM4 (1995)

P.11. J. Hebling*, E. J. Mayer*, J. Kuhl*, R. Szipöcs: Chirped-mirror dispersion-compensated OPO. Ibid. paper CThH4 (1995)

P.12. K.Osvay*, G.Kurdi*, A.P.Kovács*, Z.Bor*, R.Szipöcs: High-precision measurement of group-delay dispersion on laser mirrors. Ibid. paper CFM8 (1995)

P.13. F. Krausz*, Ch. Spielmann*, M. Lenzner*, A. Stingl* R. Szipöcs: Advances in ultrafast laser sources. *Technical Digest of the Pacific Rim Conference on Lasers and Electro-Optics 1995*, Chiba, Japan, paper FD2 (1995)

P.14. Ch. Spielmann*, M. Lenzner*, R. Szipöcs, A. Stingl*, F. Krausz*: Recent Advances in femtosecond Ti:Sapphire lasers. *Technical Digest of the OSA Annual Meeting 1995*, Portland, Oregon, USA, Optical Society of America, Washington, D.C., paper MMM1 (1995)

P.15. M. Lenzner*, Ch. Spielmann*, R. Szipöcs,. F. Krausz*, : Powerful ultrashort pulse generation in Ti:Sapphire. *Technical Digest of the IX th International Symposium on "Ultrafast Processes in Spectroscopy"* , Trieste, Italy, paper MA2 (1995)

P.16. J. Hebling*, E. J. Mayer*, J. Kuhl*, R. Szipöcs: Mirror-dispersion-compensated optical parametric oscillator. Ibid. paper ThA2 (1995)

P.17. A.P.Kovács*, G.Kurdi*, K.Osvay*, R.Szipöcs, J. Hebling*, Z.Bor* : New interferometric methods for group-delay measurement using white-light illumination. Ibid. paper FC1 (1995)

P.18. I.T.Sorokina*, E.Sorokin*, E.Wintner*, A.Cassanho*, H.P.Jenssen*, R. Szipöcs: 47 fs pulse generation from a prismless self-mode-locked Cr:LiSGaF laser. to be published in the *Technical Digest of the Advanced Solid State Lasers Topical Meeting*, Jan. 31- Febr. 2, 1995, San Francisco, CA, USA (1996)

P.19. A. Stingl*, M. Lenzner*, Ch. Spielmann*, F. Krausz*, R. Szipöcs: Sub-10-fs, mirror-dispersion-controlled Ti:sapphire laser. *Optics&Photonics News*, **6**(3) p. 48, (1995)

EDUCATION

Graduate and postgraduate courses, 1995

- Magnetism II. (P. Fazekas, ELTE[6])
- Statistical physics (F. Iglói, JATE[7])
- Solid state physics (F. Iglói, JATE)
- Advanced solid state physics I. (J. Sólyom, ELTE)
- Advanced solid state physics II. (J. Sólyom, ELTE)
- Electronic states in solids (J. Kollár, ELTE)
- Spectral theory of the Schrödinger equation (A. Sütõ, ELTE)
- Theoretical physics (S. Varró, JPTE[8])
- Quantum mechanics (S. Varró, JPTE)
- Solid state physics II. (A. Virosztek, BME[9])
- Solid state physics III. (A. Virosztek, BME)
- Mechanics (A. Virosztek, BME)
- Electrodynamics (F. Woynarovich, ELTE)
- Bethe-Ansatz (F. Woynarovich, ELTE)
- Many body problem I. (I. Tüttõ, ELTE)
- Many body problem II. (I. Tüttõ, ELTE)
- Solid state research I (I. Vincze, ELTE)
- Solid state research II (I. Vincze, ELTE)
- Solid state and materials science seminar (L. Sasvári*, I. Vincze, ELTE)
- Materials science seminar (J. Lendvai*, I. Vincze, ELTE)
- Crystalline and amorphous solids (J. Gyulai*, E. Hartmann*, T. Kemény, BME)
- Electrodynamics (G. Kriza, BME)
- Advanced materials and processes (G. Konczos, ELTE)
- Special metals and alloys (A. Lovas, BME)
- Modern physical methods in medical diagnostics (K. Tompa, ELTE)
- Experimental neutron physics (L. Cser, F. Mezei, ELTE)
- Optics and spectroscopy (Zs. Szentirmay, P. Mezei, ELTE)

[6]ELTE: Loránd Eötvös University, Budapest,
[7]JATE: Attila József University, Szeged
[8]JPTE: Jannus Pannonius University, Pécs
[9]BME: Technical University, Budapest

- Medical application of lasers (L. Csillag, Gy Farkas, Z. Gy. Horváth, N. Kroó, Medical Laser Centre)
- Lasers and photonics in forensic science (Z. Gy. Horváth, Summer course of Criminal Technical Department of National Police)
- Modern experimental methods in solid state physics (G. Faigel, ELTE)
- Experimental methods in materials science (G. Faigel, G. Oszlányi, BME)
- Physics of liquid crystals and polymers (A. Buka, ELTE)
- Lasers and laser processing (N. Kroó, I. Kertész, BME)
- Lecture held on "Theoretical aspects of magnetism and related topics", (P. Fazekas, Kudowa Zdroj, Poland)

Laboratory practice and seminars

- Solid state physics seminar (J. Sólyom, ELTE)
- Advanced solid state physics (G. Kriza, G. Mihály, ELTE, BME)
- NMR spectroscopy (K. Tompa)
- Selected modern optical laboratory measurements (Zs. Szentirmay, P. Apai, P. Mezei, Z. Donkó, L. Szalai, A. Hofmann, ELTE)
- Eperiments on amorphous alloys (I. Vincze, ELTE)
- Experimental methods in materials science (G. Faigel, G. Oszlányi, BME)
- Experimental physics (G. Oszlányi, BME)
- Experiments on liquid crystals (Á. Buka, ELTE)
- Solid state physics seminar (J. Sólyom, ELTE)
- Advanced solid state physics (G. Kriza, G. Mihály, ELTE, BME)

Diploma works

- V. Csapó (ELTE): Coexistence of superconducting and spin-density wave states (Consultant: I. Tüttõ)
- V. Sándor (ELTE): Collective excitations in layered superconductors. (Consultant: I. Tüttõ)
- P. Varga (BME): Resistivity and Hall-effect in superconducting cuprates (Consultant: A. Virosztek)
- Sz. Varga (JATE): Density functional theory of the solid-to-solid isostructural transitions (Consultant: F. Iglói)
- L. Almásy(ELTE): Study of mixed micelles by SANS (Consultant: L. Cser)
- T. Pusztai (ELTE): Studies of the phase transitons of A_1C_{60} (A=K,Rb,Cs) compounds (Consultants: I. Vincze, G. Faigel)
- P. Tóth(ELTE): Electrohydrodynamic instabilities under the influence of a magnetic field (Consultant: A. Buka)

- E. Molnár (BME): Synthesis and characterization of ester type liquid crystals (Consultant: K. Fodor-Csorba)
- Zs. Kakas (ELTE): Preparation and study of liquid crystal gel dispersion and multicomponent liquid crystal mixtures (Consultant: K. Fodor-Csorba)
- T. Paksi (ELTE): Preparation and studies of liquid crystal gel dispersions (Consultants: K. Fodor-Csorba, A. Jákli)
- Cs. Bosnyák (ELTE): Electronic structure and stability of metal surfaces (Consultant: J. Kollár)
- M. Bokor (ELTE): ^{1}H spin-lattice relaxation in $[Zn(ptz)_6](BF_4)_2$ and $[Fe(ptz)_6](BF_4)_2$ ionic crystals (Consultant: K. Tompa)
- T. Marek (ELTE): Study of ^{1}H NMR spectra in $[Zn(ptz)_6](BF_4)_2$ and $[Fe(ptz)_6](BF_4)_2$ ionic crystals (Consultant: K. Tompa)
- T. Becsei (ELTE): Giant-magnetoresistance in electrodeposited multilayers (Consultant: I. Bakonyi)
- B. Pula (ELTE): Electrical transport properties of nanocrystalline metals (Consultant: I. Bakonyi)
- I. Varga (BME): Computer control for the scanning electron microscope (Consultant: L. Pogány)
- I. Gönczi (BME): Experimental study of a nickel-metal-hydride battery prototype for vehicle applications (Consultant: L.K. Varga)
- Z. Illés (BME): Preparation and testing of a nickel-metal hhydride battery prototype. (Consultant: L.K. Varga)

Ph. D. students

Gy. Káli: Investigations of dynamical behaviour of macromolecular solutions and suspensions by the use of neutron small angle scattering. (Supervisor: L. Rosta)

P. Jóvári: Structure investigation of solutions using neutron scattering methods and quantum chemical approaches. (Supervisor: L. Cser)

L. Vitos: Electronic structure of solids (Supervisor: J. Kollár)

K. Szõcs: Fluorescence imaging (Supervisor: Z. Gy. Horváth)

T. Bereczki: Tunable laser simulator (Supervisor: Z. Gy. Horváth)

Sz. Fórizs: Application of neurochips in optics (Supervisor: Z. Gy. Horváth)

P. Nagy: Magnetic shape anisotropy (Supervisor: I. Vincze)

T. Pusztai: Fullerene thin films (Supervisor: I. Vincze)

G. Bortel: Structural study of fullerenes (Supervisor: G. Faigel)

T. Tóth Katona: Pattern formation at the interfaces of liquid crystal phases (Supervisor: A. Buka)

T. Börzsönyi: Oscillatory shear induced instabilities in nematic liquid crystals (Supervisor: A. Buka)

M. Bokor: NMR relaxation in Fe and Zn ionic crystals (Supervisor: K. Tompa)

T. Marek: NMR spectra in Fe and Zn ionic crystals (Supervisor: K. Tompa)

J. Garaguly: Mechanism of hydrogen absorption and desorption (Supervisor: A. Lovas)

I. Varga: Magnetic domain contrast studies and image processing by SEM (Supervisor: L. Pogány)

Said H. Moustafa: Amorphous carbon thin layer; structure and macroscopic physical properties (Supervisor: M. Koós)

Dissertations

I. Tüttõ: Bound states in broken gauge invariance systems (Doctor of Physical Science)

T. Grósz: Investigations on aqueous solutions of TMU by neutron scattering methods (Candidate of Physical Science)

J. Tóth: Study of atomic and electronic structure changes by thermopower and electrical resistivity measurements in alloys and high-T_c ceramics (Candidate of Physical Science)

P. Jani: Laser measurement systems based on classic light scattering (Candidate of Physical Science)

I. Pócsik: In vitro proton NMR investigations of water content of biological tissues (Candidate of Physical Science)

L.K. Varga: Conduction band s and d electrons in amorphous transition-metal-metalloid alloys (Submitted for the degree of "Candidate of Physical Science")

L. Pogány: Materials research by SEM (Submitted for the degree of "Candidate of Technical Science")

Z. Donkó: Properties and modeling of glow discharges in the cathode region (Submitted for the degree of "Candidate of Physical Science")

I. Jánossy: Light induced changes in liquid crystals and amorphous semiconductors (Submitted for the degree of "Doctor of Physical Science")

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