YEARBOOK

CENTRAL RESEARCH INSTITUTE for PHYSICS

OF THE HUNGARIAN ACADEMY OF SCIENCES

1987–88

YEARBOOK
1987–88

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PREFACE

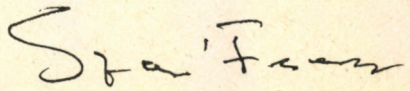
This book covers the activities of the Central Research Institute for Physics of the Hungarian Academy of Sciences from January 1987 to December 1988. The research centre, generally known by the Hungarian abbreviation KFKI, comprises five research institutes and some central facilities, jointly covering a fairly wide spectrum of fundamental and applied research in physics, materials sciences and engineering. In the first part of this Yearbook some important collaborative efforts are discussed.

The discovery of high-temperature superconductors has induced considerable interest in both the fundamental processes and the materials involved. Scientists in several institutes of KFKI had the necessary background for successful research in this highly competitive field.

The Chernobyl accident called public attention to the vital importance of proper training for reactor operators, preparing them for all sorts of emergency situations. Our expertise and experience in reactor physics and in computerized process control were combined to develop a training simulator to be installed in the nuclear power plant at Paks, Hungary.

A third report describes the reconstruction and updating of KFKI's own research reactor. The improved facility will provide better support for several fields of activity, in particular for solid-state physics research and isotope production.

After a general progress report describing the activities of the five research institutes and those of the Computing Centre and the Development Engineering Division, a complete list of conferences and discussion meetings organized by NEFIM, the Centre for International Workshops in Theoretical Physics is given, followed by a list of KFKI preprints and reports published in 1987-88.



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CONTENTS

RESEARCH OF HIGH TEMPERATURE SUPERCONDUCTORS

High temperature superconducting oxides were discovered in 1986 by Alex Müller and Georg Bednorz [1]. In December 1986 the discovery was confirmed by the Shoi Tanaka group in Japan, and the January 1987 issue of Physical Review Letters carried two papers by American scientists on the new materials. The feverish research on high temperature superconductivity began in early 1987. Now, at the end of 1988 we can review major breakthroughs, and we can see the yet unanswered questions more clearly.

In early 1987 several research teams of the KFKI, the Central Research Institute for Physics, launched a coordinated effort for the investigation of the novel materials. The first superconducting oxide was prepared in January, 1987 here, by a group in the SzFKI (Fig. 1). We were able to join the world wide efforts without substantial investment by relying on our instrumentation and our experience in various aspects of material preparation. We used the existing measurement capabilities of KFKI in the investigation of the new compounds. Complex studies, relying on international cooperation, were performed in the RMKI, MKI, AEKI and SzFKI.

Investigations of Pure and Doped La_2CuO_4

Using the co-precipitation method of Bednorz and Müller [1] we reproduced the preparation of the mixed phase La-Ba-Cu-O compound with a transition temperature T_c=28K (Fig. 1). Our early efforts were concentrated on the La-Sr-Cu-O system and on the undoped parent compound La-Cu-O. The undoped system is orthorhombic at room temperature. In the study of the structure and of the superconducting properties at different Sr contents we concluded that the structural transition, illustrated in Fig. 2, correlates with the presence of the superconductivity. This observation is in accordance with the phase diagram, based on the results of more detailed investigations.

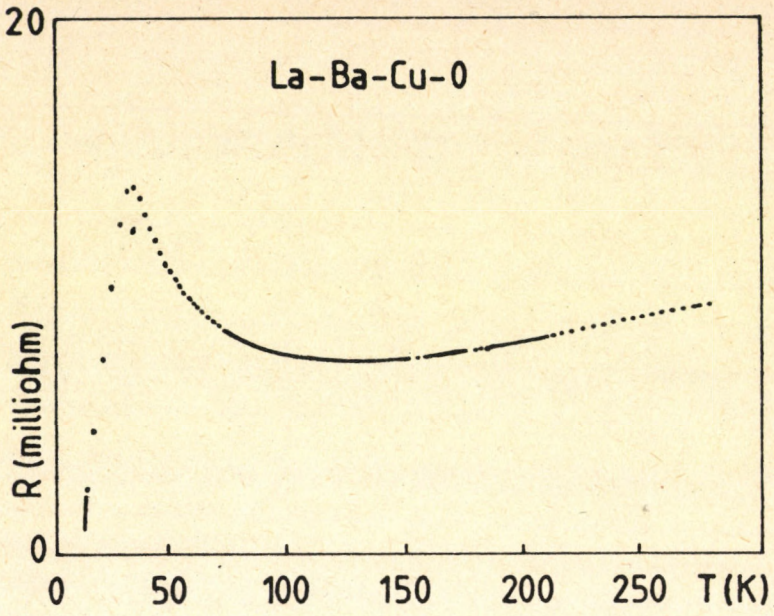

Fig. 1

Temperature dependence of the resistivity for the first La-Ba-Cu-O ceramic sample prepared in KFKI. The material shows incomplete superconducting transition.

The major disadvantage of the co-precipitation method is the somewhat uncontrolled shift of the composition of the final product relative to the original composition. Thus we turned to the generally applied oxide mixing method. We prepared pure La-Cu-O samples with various La/Cu ratios by the two methods and we performed resistivity measurements on these samples. We made efforts to prepare samples in high pressure oxygen atmosphere as well. A resistivity decrease was detected at low temperatures, and the anomalously high magnetoresistance (Fig. 3) indicated that the resistivity decrease is due to superconductivity. Our results were confirmed by other groups, although the nature of the superconducting phase is not clear. Possible candidates are surface superconductivity, La rich intermediate phases (different from the semiconducting La_2CuO_4), or impurity effects. The proton PIXE measurements of these samples are particularly important in this respect, since with them, a number of possible impurities were excluded.

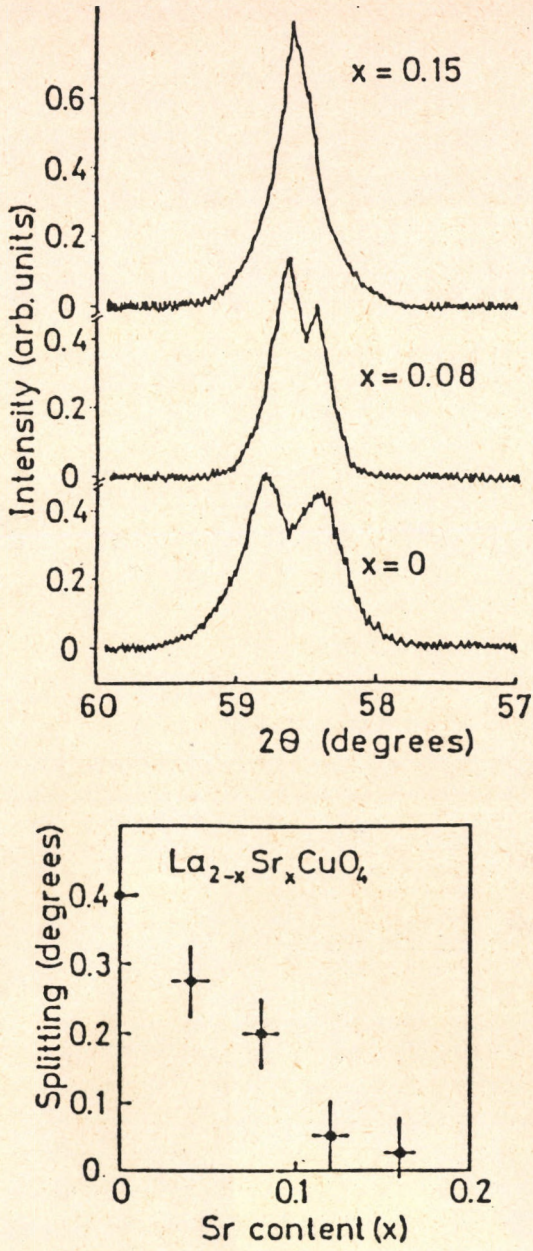

Fig. 2

The pure La_2CuO_4 is orthorhombic at room temperature and doping with Sr results in a tetragonal structure. The X-ray powder diffraction pattern of $La_{2-x}Sr_xCuO_4$ (upper curves) exhibits a splitting characteristic of the orthorhombic distortion for x=0 and x=0.08. The lower curve shows the splitting, measured at room temperature, as a function of Sr content.

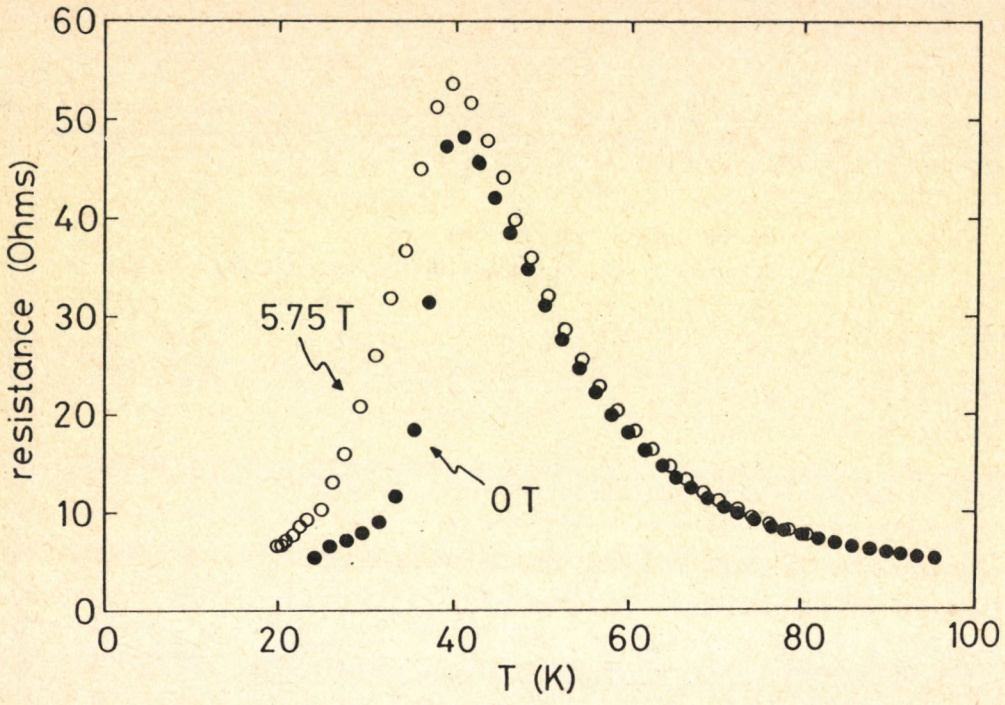

Fig. 3

Temperature dependent resistivity of a La-Cu-O sample with and without magnetic field. The anomalously high magnetoresistance below 40K serves as additional evidence for superconductivity in the undoped specimen

Preparation of 1:2:3 Compounds

In February 1987 new materials were discovered with a transition temperature higher than 77K, the boiling point of liquid nitrogen. We prepared the first compound of this type in March 1987. The structure and the composition of the superconducting phase ($YBa_2Cu_3O_{7-\delta}$) became known, and the related compounds of metal ion composition 1:2:3 were prepared. The oxygen content of the compounds proved to be variable in the range of $\delta = 0.0\text{-}1.0$. Our efforts were concentrated on three aspects of material preparation:

- production of homogeneous $YBa_2Cu_3O_7$ samples in large quantities for neutron scattering studies
- systematic variation of the oxygen content for NMR, NQR, neutron scattering, infrared and Raman scattering measurements
- iron and cobalt doping of $YBa_2Cu_3O_{7-\delta}$, and preparation of $EuBa_2Cu_3O_{7-\delta}$ samples for Mössbauer studies.

These efforts were successful and we supplied appropriate samples for measurements made in the KFKI and, in cooperation with our partners, in other institutions in Hungary and abroad. Since the ceramic technology of the sample preparation is relatively simple, there is a strong international competition in the material preparation. Therefore, we emphasized the complex material characterization, including X-ray scattering, resistivity and magnetic susceptibility measurements and scanning electron microscopy. Rutherford back scattering, differential thermal calorimetry and gravimetry have also been performed on some samples. We supported high resolution electron microscopy studies at the Solid State Physics Department of the Eötvös University. The scale of the sample preparation efforts can be illustrated by the fact that more than 100 resistivity vs. temperature measurements have been made on the $YBa_2Cu_3O_{7-\delta}$ material alone.

Tl-Ba-Ca-Cu and Bi-Sr-Ca-Cu Systems

The intensive research of the rare-earth — copperoxide materials was aimed in part at the general description and better understanding of these materials. Significant efforts were also made to increase the T_c on an empirical basis. Several publications dealt with the possible signature of superconductivity above the generally accepted transition temperature $T_c \approx 95$ K of the well known $YBa_2Cu_3O_7$ material. Nevertheless, the conclusions of these papers remained irreproducible and questionable.

January 1988 brought new developments in this area. The Bi-Sr-Cu-O system, which does not contain rare earth elements, was known to be superconducting with $T_c \approx 8$ 22 K. The introduction of Ca in this system by H. Maeda and his co-workers [2] led to the discovery of a series of materials exhibiting superconductivity above 100 K. The highest transition temperature, $T_c \approx 125$ K was found in Tl-Ba-Ca-Cu oxides. Actually, the "Bismuth" and "Thallium" materials are structurally very similar. Members of both families can be synthetized by adding "$CaCuO_2$" units to $Bi_2Sr_2CuO_6$ or $Tl_2Sr_2CuO_6$. The structural investigations revealed that these materials are also oxygen deficient perovskites. The unit cells of three members of the series for the "Thallium" material were determined by Sleight and co-workers [3]. The corresponding "Bismuth" material can be created by exchanging Bismuth and Strontium for Thallium and Barium, respectively. Apparently the CuO_2 sheets are present (like in the La-Sr-Cu-O or in the "1:2:3" materials), and they are separated by the oxygen free calcium layers. The Tl-O (Bi-O) double layers are situated between the Ba-O (Sr-O) sheets, in a position which is similar to that of the Cu-O chains of the 1:2:3 compounds.

Utilizing the benefits of private communication, we managed to prepare the first Bi-Ca-Sr-Cu-O samples before the first publications appeared in the literature. The isolation of a pure superconducting phase proved to be more complicated than that of the 1:2:3 compounds, and the typical sample consists of a mixture of materials with different compositions. Scanning electron microscopy and microprobe measurements, complemented by X-ray diffraction (a joint effort of the KFKI and the HUNGALU Research and Development Institute), indicated that the typical Bi Ca Sr Cu O sample consists of at least four distinct phases, and the relative amount of the phases depends on the cooling rate and other parameters of the sample preparation. More recently we have been able to produce samples of $Bi_2Sr_2CaCu_2O_y$ in a relatively pure phase. Our results indicate that the transport properties of the compound also depend on the oxygen concentration.

Single Crystal Preparation

The preparation of single crystals is very important from the point of view of basic research. It is well known that the compounds are anisotropic and measurements on ceramic samples give information averaged over the different directions. Good quality surface, required for some studies, can be obtained with single crystals or thin films.

Our efforts in this field are based on the experience in single crystal growth at MKI. Several methods have been tested. For the so called "flux method" the components of the material are dissolved in a low melting point salt like KCl. Another way of growing single crystals is based on melting the components in the presence of excess CuO. The crystals are obtained when the system is slowly cooled over a temperature range specific to the material in preparation. To find the right ratio of components and the proper cooling program, or to create an appropriate temperature gradient in the system makes crystal growing a branch of science in itself.

The most significant difficulty we encountered is related to the extreme chemical activity of the melts containing copper oxide. Expensive platinum crucibles are easily dissolved. Therefore in most of the experiments much cheaper alumina crucibles were used, but these are also susceptible to degradation by the melt. Another problem comes from the fact that the phase diagram of the system is not known. The sensitivity of the system to the partial oxygen pressure further complicates the phase diagram.

In spite of these difficulties we grew single crystals of the 1:2:3 compounds (with Y,Eu,Dy,Sm,Er and Nd at the rare-earth site) and $Bi_2Sr_2CaCu_2O_y$. The size of the typical crystal from the 1:2:3 materials is

1 mm × 1 mm × 0.02 mm. Electrical resistivity and magnetic susceptibility measurements detected the superconductivity of the crystals. Oxygen treatment of the $YBa_2Cu_3O_{7-\delta}$ crystal improved the superconducting properties. The optical reflectivity measurement, presented in Figure 4, was made at the University of Florida, Gainesville (USA).

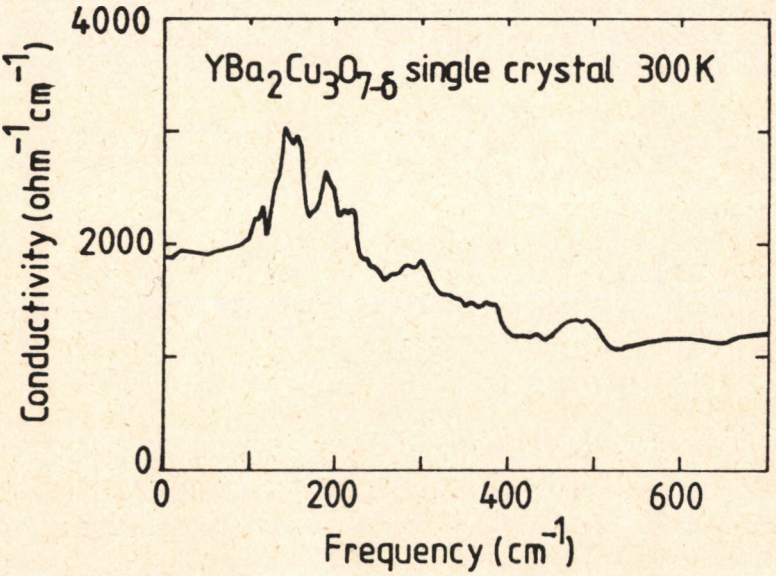

Fig. 4

Optical conductivity of the $YBa_2Cu_3O_{7-\delta}$ single crystal prepared in the KFKI. The superconducting transition temperature for this crystal is T_c=85K

The $Bi_2Sr_2CaCu_2O_y$ crystals are larger, but their thickness is similar to the 1:2:3 crystals. The 1:2:3 material exhibits a tetragonal to orthorhombic phase transition, and at low temperatures the crystals are twinned. It is expected that the $Bi_2Sr_2CaCu_2O_y$ crystals are not twinned. The size of the crystals is sufficiently large for tunneling and proximity effect measurements.

Up to now the best single crystals were obtained from the partially melted copper-oxide rich mixture. The "flux method" was also tested and it seems to be very promising. Attempts were made to prepare epitaxial thin films by immersing single crystal substrate into the melt. A polycrystalline superconducting layer was observed and further studies are in progress to find the appropriate substrate material.

Influence of Oxygen Content on Phonon Density of States of $YBa_2Cu_3O_{7-\delta}$

Because of the unavailability of the nuclear reactor in the KFKI during the reconstruction, neutron scattering measurements were performed in Saclay, Grenoble (France) and in the Rutherford Laboratory (England). The structure of $YBa_2Cu_3O_{7-\delta}$ was studied by elastic neutron scattering. Time-of-flight spectrometry was used in the study of phonon density of states (DOS). We did not find evidence for phonon softening at low levels of energy, but a pronounced change in the DOS was observed in the energy range of 17-22 meV (Fig. 5a). In a complementary study we investigated the phonon modes by Raman spectroscopy (Fig. 5b). The results of the two investigations are in accord with each other; the Raman measurements identify the optical phonon modes.

The conclusion of these studies is that the conventional phonon mediated electron-electron interaction is not likely to explain the superconductivity in these compounds. No evidence was found for soft phonon modes, required for the anomalously high transition temperature.

Another candidate for the coupling between the electrons is the Coulomb interaction. In many cases the Coulomb interaction leads to strong magnetic coupling. Therefore we investigated the magnetic

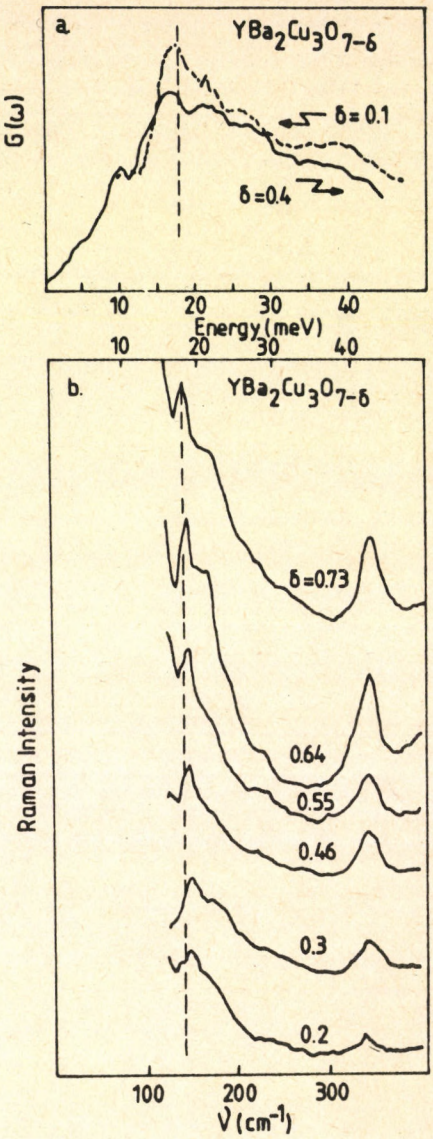

Fig. 5

The upper curves show the generalized phonon density of states for two $YBa_2Cu_3O_{7-\delta}$ samples of δ=0.1 and δ=0.4, measured by time-of-flight neutron spectroscopy. The lower curves are the results of Raman spectroscopy on a series of samples with different oxygen contents.

properties of the compound at different oxygen contents. The goal of these studies was to search for magnetic fluctuations in the superconducting material. The results are summarized below.

Magnetic Fluctuations

The antiferromagnetic order in the oxygen deficient $YBa_2Cu_3O_{7-\delta}$ with $\delta=1.0$ was recognized quite early. We investigated the magnetic scattering of polarized neutrons for a series of $YBa_2Cu_3O_{7-\delta}$ compounds with $7-\delta=X=6.15,6.34$ and 6.59. About 50 grams of ceramic sample was prepared for each composition by the appropriate heat treatment. The variation of the oxygen content of the samples was monitored by the measurement of the weight of the samples between the heat treatments. In addition to this the absolute value of the oxygen content was determined from the Rietveld refinement of the elastic neutron scattering spectrum. The results of the two methods agreed within the experimental error of $\Delta X=0.03$.

The sample of $X=6.59$ was found to be orthorhombic and superconducting at the transition temperature of $T_c=47K$. The other samples were tetragonal semiconductors.

We observed antiferromagnetically ordered magnetic moments in the samples of $X=6.15$ and $X=6.34$. There was no magnetic order in the sample of $X=6.59$. In addition to the ordered magnetic moments, we observed neutron scattering due to disordered magnetism, even at the lowest temperature of the measurement, $T=1.5K$. Disordered moments were present in the superconducting sample of $X=6.59$ as well. The diffuse magnetic scattering of the disordered moments gradually disappeared at higher temperatures.

The results were tentatively interpreted in terms of magnetic fluctuations, with a temperature dependent time scale crossing over the characteristic time scale of the neutron scattering measurement. The presence of magnetic fluctuations in the superconducting sample is most surprising, and further investigations are planned.

Influence of Oxygen Content on the Transition Temperature of $YBa_2Cu_3O_{7-\delta}$

We studied extensively the relationship between the transition temperature and the heat treatment of the sample during the preparation. It was recognized by many groups that there is a wide oxygen composition range for which the transition temperature is close to $T_c=60K$. Other groups observed a monotonous decrease of the transition temperature as the oxygen content

was decreased. According to our results [4], presented in Figure 6, the plateau in the transition temperature vs. oxygen content curve is related to a special feature in the heat treatment of the sample: it is nearly independent of the cooling rate at high temperatures, but it strongly depends on the time spent around 400 °C. Long equilibrating treatment at this temperature results in a well developed plateau. The results can be related to the diffusion dynamics of the oxygen.

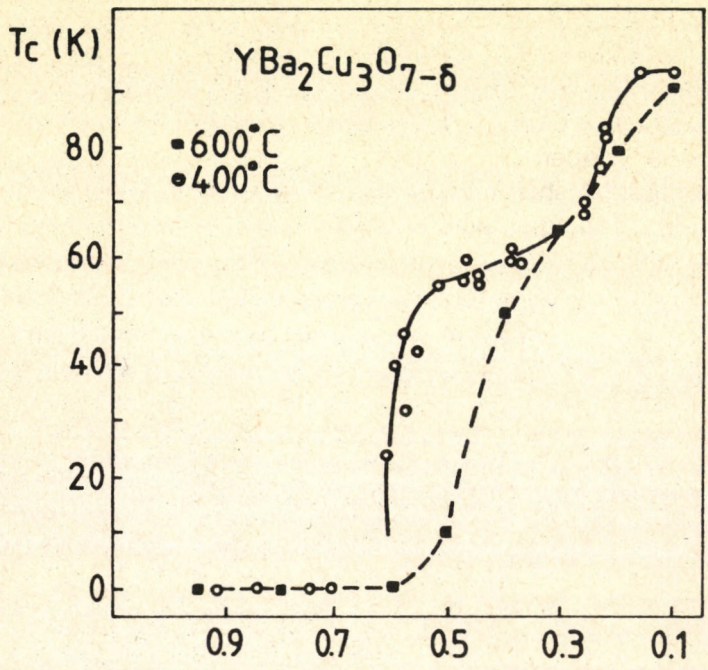

Fig. 6

Superconducting transition temperature (T_c) vs. oxygen deficiency (δ) for two sets of $YBa_2Cu_3O_{7-\delta}$ samples. The two sets differ in the so called "equilibration temperature" (600 °C and 400 °C for the full and empty symbols, respectively), a characteristic temperature of the heat treatment of the samples.

NMR and NQR Investigations

In cooperation with the Institute of Chemical Physics in Tallin, USSR we performed nuclear magnetic resonance (NMR) and nuclear quadrupole resonance (NQR) measurements in $YBa_2Cu_3O_{7-\delta}$. In the KFKI we determined the NQR frequencies of the two crystallographically different copper sites. The NMR results, obtained in high magnetic fields, were evaluated by using the NQR data. The assignement of copper sites and NQR frequencies was controversial for a while. We attempted to clarify the situation by comparing the NQR spectra of the $\delta=0$ compound and the slightly oxygen deficient $\delta=0.15$ material. Neutron diffraction investigations by several groups indicated that the oxygen deficiency primarily affects the oxygen sites in the copper oxygen chains, and the copper oxide planes are not changed. The NQR results presented in Figure 7 show that the low frequency NQR signal is nearly destroyed by a small oxygen deficiency; therefore this signal should belong to the chain site. This question was investigated by other methods as well, and the final settlement of the controversy came from the single crystal measurement of C.P. Slichter's group [5].

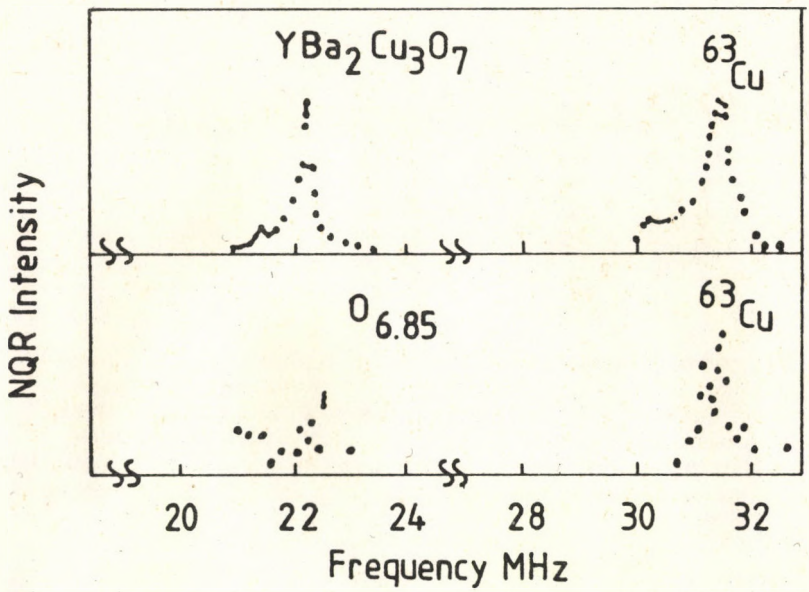

Fig. 7

^{63}Cu NQR spectra for a $YBa_2Cu_3O_7$ and for a $YBa_2Cu_3O_{6.85}$ sample. The peak around 22 MHz is very sensitive to the oxygen content, indicating that it belongs to the copper in the copper oxygen chains.

The ^{139}La NQR spectrum of pure La_2CuO_4, obtained by Kitaoka et al. [6], has been evaluated by taking into account the localized magnetic moments in this compound. The local magnetic fields, due to ordered magnetic moments on the copper sites, generate a nine line NQR spectrum (Fig. 8). The frequencies of all nine peaks found by Kitaoka et al. can be fitted within a few percent. The comparison of the experimental results and the calculation excludes the possibility of a simple "chessboard type" antiferromagnetic order in this compound.

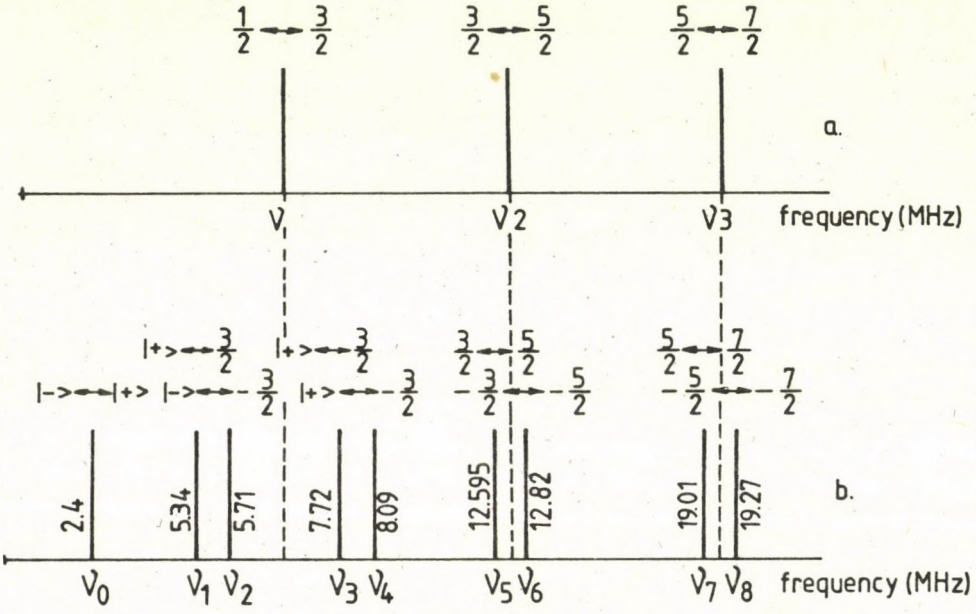

Fig. 8

The transition frequencies of the ^{139}La NQR spectra in La_2CuO_4 without and with magnetic order.
(a) There are three lines at the frequencies with ratios 1:2:3 if the EFG tensor is axially symmetric and there is no local magnetic field present.
(b) The local magnetic field due to the magnetic order of the moments localized at the copper sites splits the three lines into nine, in accordance with the experimental spectrum.

We investigated the ^{203}Tl and ^{205}Tl NMR in multiphase Tl-Ba-Ca-Cu-O samples of different compositions. The goal of these studies was to determine the conduction electron density at the Tl site, and to decide if the Tl is in a metallic or ionic state in this compound. We concluded that the Tl is not in a metallic state.

Mössbauer Studies

The goal of the Mössbauer experiments is twofold. First, we want to uderstand the rules governing the doping by the elements needed for the Mössbauer measurements. Second, we want to study the properties of the doped material. Conduction electron density, electric field gradients, magnetic order etc. can be studied at the impurity sites.

Extensive Mössbauer spectroscopic studies were made on ^{57}Fe and ^{57}Co doped $YBa_2(Cu_{1-x}M_x)_3O_{7-\delta}$ with $\delta=0.0$ and 0.8 in the RMKI. The dopant (M) concentration was varied between $x=3.5\times10^{-5}$ and $x=0.1$, and emission and absorption spectroscopy was performed in the temperature range of 4.2K to 295K, with and without the application of external magnetic fields. Typical spectra for the iron doped, $x=0.1$, $\delta=0$ material is shown in Figure 9 at different temperatures and magnetic fields.

Four iron species were observed with relative dominance depending on the composition parameters x and δ. We established that, under the preparation conditions of our samples, the dopant preferentially substitutes the Cu(1) crystallographic copper site. Evidence was found for Fe^{4+}, a rather exotic state, in the host matrix of $YBa_2Cu_3O_{7-\delta}$. Antiferromagnetism was observed at dopant concentrations $x=0.10$ and $x=0.06$ at the temperature of T=4.2K. This is, however, not directly related to the antiferromagnetic order of the magnetic moments localized on the copper sites of the oxygen deficient host material.

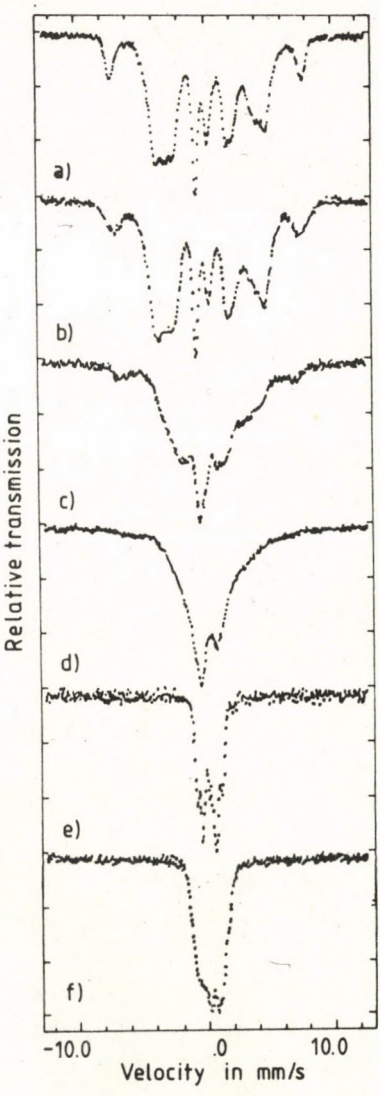

Fig. 9

Mössbauer spectra of $YBa_2(Cu_{1-x}Fe_x)_3O_{7-\delta}$ with $x=0.1$ and $\delta=0.0$ at different temperatures (T), with and without external magnetic field (H). (a) T=4.2 K, H=OT, (b) T=4.2K, H=5T, (c) T=15K, H=OT, (d) T=19 K, H=OT, (e) T=100K, H=OT, (f) T=100K, H=5T

Mössbauer spectroscopy was also performed on iron doped Bi-Sr-Ca-Cu oxide. We plan to extend the investigations to Sn doped materials as well.

Positron annihilation studies of $YBa_2Cu_3O_{7-\delta}$ were performed and a lifetime-anomaly was observed around 240K. Further investigations are planned to clarify the origin of this anomaly and to exploit the potentials of the positron annihilation method on single crystal samples.

Application Oriented Research

In cooperation with the Research Institute for the Electrical Industry (VKI), the explosive compression of the ceramic material and its effect on the electrical and magnetic properties were studied. Preliminary studies were also carried out on wires made of ceramics embeded in various filling materials. We found that the process is potentially suitable for manufacturing "ceramic" superconductor wire. However, the technological aspects have not yet been dealt with.

The parameters of processing and their effects on the superconducting properties were studied in collaboration with KOPORC Electronic Component Company. It is worth noting that the attempt to produce pliable superconducting foils with thickness in the order of $\sim 100\ \mu$ were successful.

Concluding Remarks

Bednorz and Müller were awarded the Nobel prize in September, 1987. By that time it was widely understood that they had identified the superconducting phase in the investigated material, and that the highest transition temperature was held by a compound of different composition, synthesized by another group. Bednorz and Müller made a fundamental contribution to science, however, by attracting the interest to a new family of materials. The microscopic theory of conventional superconductors based on the phonon mediated electron-electron interaction does not seem to describe the superconductivity in the new compounds. The experiments performed during the last two years indicate that the electron-electron coupling is more likely related to the antiferromagnetism observed in the oxygen deficient compounds.

In the preparation of the materials our efforts were concentrated on the reproduction of the results obtained in other laboratories. Considering the large number of research groups working on new materials (and the resources available to them) we did not attempt to set "world record" transition tem-

peratures on a trial and error basis. Instead, with the help of the theoretical solid state physics group in the KFKI, we tried to find the experimental methods leading to the better understanding of the phenomenon, and we performed measurements on well characterized samples prepared in our institute. The international cooperation with several leading experimental groups proves that we were quite successful in the material preparation and in the identification of relevant experimental methods. Some of our papers have attracted considerable interest and are widely cited in the literature.

The research of the high temperature superconductors in the KFKI was supported in 1987 by the OMFB grant #70-06-0270 and in 1988 by the joint funding of IpM, OMFB and MTA under grant #7-06-04751/1. About 80% of the work was done by using the reserves and resources of the KFKI. The funding helped us to improve the instrumentation of experimental solid state physics in general.

Part of the resources available to us was used for diffusing up to date information on the new discoveries. We supported the publication of the lecture material of the Autumn School of the Eötvös Loránd Physical Society, and we financed the proceedings of the International Conference of Low Temperature Physics, held in Budapest, 1987. We also published the texts of the talks given at the Meeting of the Physics Teachers (Eötvös Loránd Physical Society, 1988). A number of articles have been written by scientists of the KFKI for popular science magazines in Hungary, and we were glad to accept invitations for talks in different parts of the country.

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DEVELOPMENT OF TRAINING SIMULATORS FOR NUCLEAR POWER PLANTS

Introduction

Training simulators for nuclear power plant (NPP) operating staff have gained increasing importance over the last twenty years. The need for training simulators was clearly recognized as a result of analyzing the operators' errors that led to severe accidents at Three Mile Island and Chernobyl. Research was started in the early eighties in our Institute to develop training simulators for VVER-440 type nuclear power plants. The effort involved two projects:

— the development of the basic principle simulator for VVER-440 NPPs,
— the development of the full-scale (replica) simulator of the Paks NPP.

These two simulators complement each other because they play different roles in operator training. Basic principle simulators are used for initial training in fundamental plant concepts. They provide a thorough understanding of the basic physical phenomena governing the behaviour of the most important plant systems (e.g. reactor, turbine, etc.). Full-scope simulators are plant specific and are used for training and retraining in all operating procedures covering start-up, shutdown and operation during normal, abnormal and emergency situations.

Both projects were completed at the end of 1988. This paper summarizes the results of the research and development in this field.

Modelling of Nuclear Power Plants

Real-time modelling of the complex processes of nuclear power plants requires:

- a thorough understanding of the physical phenomena to be modelled,
- modelling experience in formulating the problem properly,
- mathematical skill to solve the formulated problem effectively,
- a multitude of experiments to determine the permitted simplifications and their effect on the accuracy and on the transient behaviour,
- accurate transient measurements for fitting the tunable parameters of the models.

All this makes one well-tested and verified model a very valuable product.

The real-time modelling of nuclear reactors and other plant related systems was started in the Institute by modelling the VVR-SM research reactor for developing its computerized control system. When this work was completed the model development continued by modelling nuclear power plant technological units for using them in on-line disturbance analysis systems. This model development led us to the decision to develop a basic principle simulator for VVER-440 power plants as our gained experience and modelling skill seemed to be sufficient for this project. However, it was also evident that our experience in this field was not enough for developing a full-scope simulator; therefore, a joint Hungarian — Finnish project was started (with the NOKIA Corporation) in 1984 to develop a replica simulator for the Paks NPP.

Basic Principle Simulator

In this simulator the plant control room is replaced by a control desk with indicators for the most important process variables and with the essential control devices. The operation of the VVER-440 power plant is simulated in the power range during steady state and transient situations. The most important simulated transients include:

- reactor trip,
- control rod failure,
- stop of a main circulating pump,
- pressurizer heater failure,
- turbine trip,
- loss of load,
- bypass valve failure, etc.

Variables which are not directly measured in the real plant but are important for the control of the process (e.g.: fuel temperature, Xe concentration, etc.) are also indicated on the control desk. Moreover, there are alarm annunciators on the control desk which signal when abnormal situations occur (e.g. trip limits are approached).

The hardware configuration of the simulator is shown in Fig. 1. The simulator consists of three parts:

— simulator computer
— control desk
— instructor's display station.

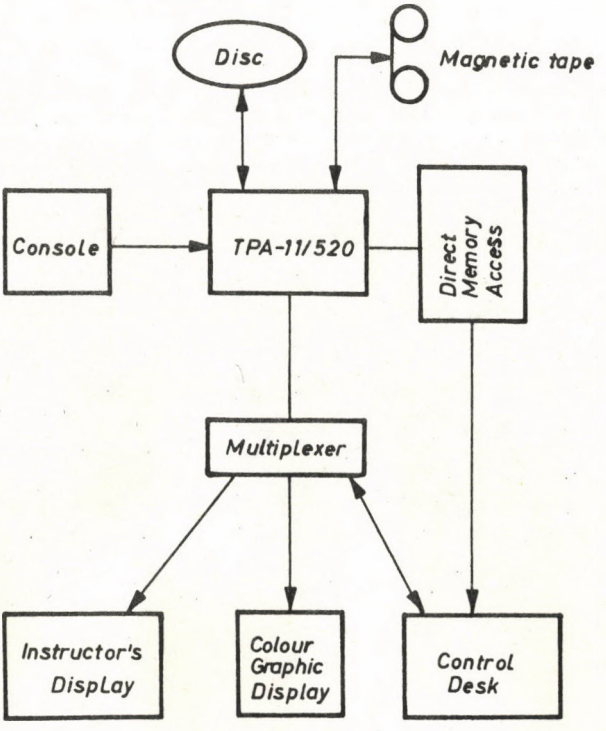

Fig. 1

The simulator computer is a TPA-11/520 type machine which is a VMS compatible high-speed and powerful megamini. Its MOS-VP operating system is a virtual memory operating system supporting real-time applications.

The control desk (Fig.2.) is a specially designed peripheral with a microprocessor based interface system which minimizes the CPU load. It is completely modular, built from mosaic tiles, thereby providing flexibility for later

changes. A colour graphic display complements the desk. This display is used to present the time-history of the most important variables. The system stores up to 32 selected variables automatically in every simulation cycle and displays them in groups of six. This feature is similar to the operation of a conventional strip recorder, but it is much more flexible and powerful.

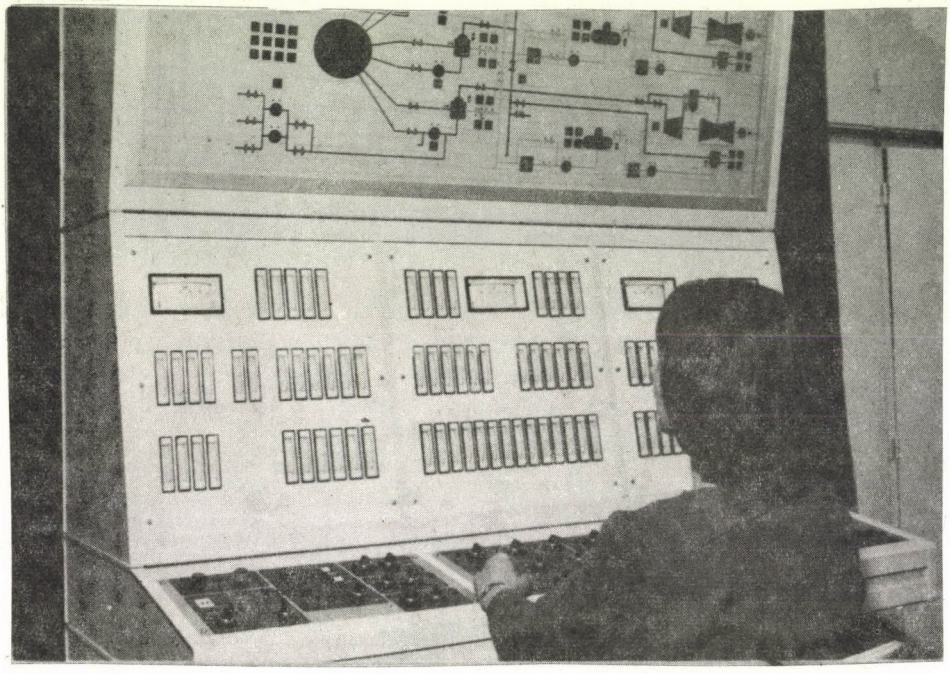

Fig. 2

The instructor's display is a standard alphanumeric terminal. From this terminal the instructor can

- initialize a simulation session,
- freeze or restart the simulation,
- change different external parameters,
- start malfunctions,
- request different evaluation logs,
- go back in time (backtracking).

Our Institute has taken part in the Coordinated Research Program on "Development of Common Modelling Approaches for Nuclear Power Plant Training Simulators" of the International Atomic Energy Agency and the whole model development of this simulator was offered to the Agency as a Hungarian contribution to the Program. The available reports are listed at the end of the paper.

Full-scope Simulator

The basic requirement of the full-scope simulator is to provide a replica control room of the Paks NPP in which all the procedures can be practiced which may be required in the real plant.

This requirement is very strict since in the control room many thousands of variables can be seen (in the control panels and in the display units of the plant computer), and all of them have to be simulated by a huge real-time system.

The hardware configuration is shown in Fig. 3. It contains the following main parts:

- simulator computer complex,
- control room interface system,
- plant computer system,
- control room instrumentation,
- instructor's system.

The simulator computer is composed of two high-speed TPA 11/580 processors connected to each other by a multiport memory. This memory forms the common data base of the whole system and every common variable is stored there. Both processors have their own disc storage system and other standard peripherals.

The control room interface system contains eight intelligent CAMAC crates providing many thousands of input/output lines. The tasks of this subsystem are:

- to scan all of the controllers of the control desks (switches, pushbuttons, etc.) ten times per second and to send the changes to the simulation computer,
- to convert the values of the output variables from floating point representation to analogue signals, and to add noise to the output,
- to simulate the operation of some very sophisticated measuring devices of the control room (e.g. synchronoscope).

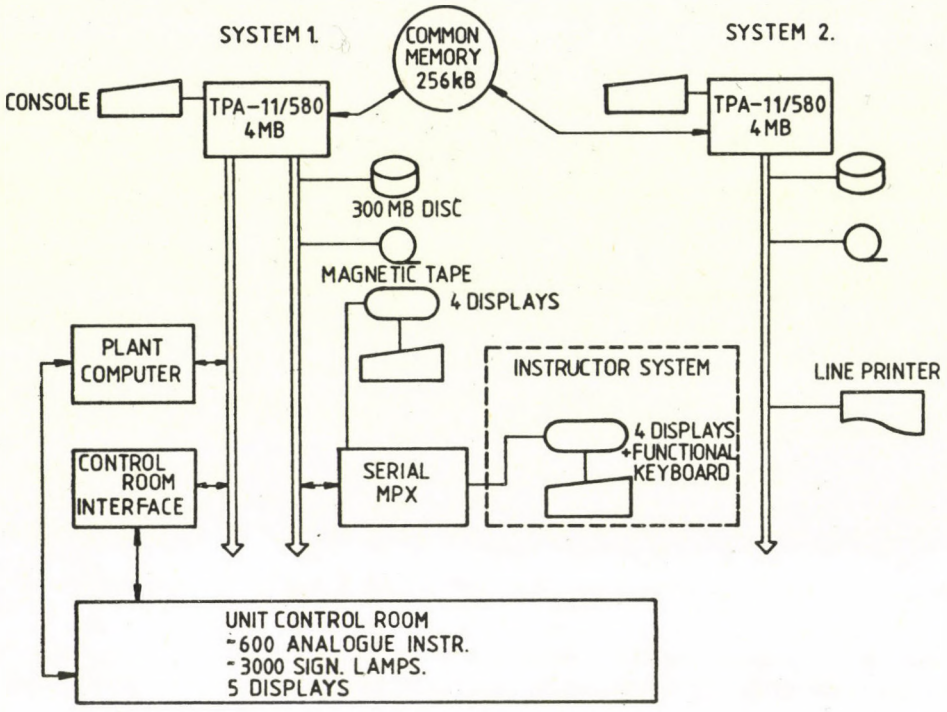

Fig. 3

The total number of the I/O signals are as follows:

analogue output:	670
digital output:	6200
analogue input:	49
digital input:	2100
controllers:	105

The control room imitates the main control room of the plant; the operators' desks, as well as the front and side panels are the exact replicas of the original ones. Almost all the indicators and devices of the control room are identical to those in the real plant except for a few special instruments.

The plant computer of the Paks NPP is an advanced system providing different CRT formats and printing a great variety of logs. It incorporates the VERONA core monitoring system. Because of this, it was more economical to reproduce the plant computer for the simulator than to simulate its operation by means of some other computer. This was relatively easy to do as it was our Institute that supplied the plant computer for Units 3 and 4 of the Paks

NPP. Since the reliability required of the plant computer in the simulator is not so strict as in the real plant, the plant computer contains a single TPA 11/440 computer connected to the simulator computer via a Direct Memory Access channel. This computer drives six colour graphic display units and two line printers in the control room.

The instructor is situated in a special room separated from the control room but affording good visual contact with it. From his desk the instructor can monitor and supervise the simulation process and the trainee's performance. The instructor's desk accomodates the following devices:

— two alphanumeric display units,
— two colour graphic display units,
— a special functional keyboard,
— a telephone set.

The instructor's graphic displays are identical to those of the control room, thus the instructor may choose any CRT format available.

The simulation models cover the whole range of operations of the plant from cold shutdown state to full power level. Furthermore, a very wide range of abnormal operating conditions are also simulated. The most important malfunctions are the following:

— control rod stuck or dropped,
— pressurizer heater failure,
— leak in pressurizer blowdown valve,
— loss of main circulating pump power,
— leak in pressure accumulator check valve,
— loss of coolant accident (LOCA),
— pipe rupture in the steam generator,
— leak in the feedwater connection piping of the steam generator,
— turbine control valve stuck,
— loss of turbine lube oil,
— loss of ejectors and condenser vacuum,
— air leakage to condenser,
— HP/LP heater tube leak,
— loss of generator excitation,
— loss of generator cooling,
— disconnection of the 400 kV line,
— failure in the Diesel aggregate,
— failure in the unit power controller (ARM).

A very important feature of this simulator is that standard models and centralized solutions are used to minimize the programming and testing work. Pressures, temperatures and flows in the piping networks are treated with

the THLF package (Thermal Hydraulic Load Flow) which is used for one phase flow calculations and simulates about 90% of all pumps, valves and pipes. The electrical networks are calculated by the ELNET package. Both packages are based on the same sparse matrix solution technique. A special programming tool is used to simulate the plant logics and interlockings. Based on the logic diagrams of the plant, these logics are described by Boolean algebraic equations using variable names closely resembling the real plant names. A precompiler compiles the source descriptions of the logics into a FORTRAN code. All of the models are FORTRAN codes in order to minimize the programming and testing effort.

To develop such a huge real time program within a strict time schedule is highly demanding because

— it requires extensive programming effort,
— there are many interactions among the different models,
— continuous modification is required during the life of the simulator.

The basic simulation cycle time is about one second except for some fast subsystems (e.g. neutron kinetics) which are calculated four times in a cycle. The full-scope simulator is shown in Fig.4.

Full-scope Simulator Project

The full scope simulator was constructed as a joint project of NOKIA Electronics, Finland, and our Institute with a close cooperation with the Paks NPP. The Contract for the construction came into force in August 1984. The data collection and data delivery for the functional specification was completed by the end of 1984. The functional specification was completed by May 1985 and the Technical Design was finalized in November 1985. From this time parallel projects started, one in Helsinki and one in Budapest. The off-line model development was carried out by a mixed Finnish-Hungarian team in Helsinki, while the whole hardware, control room interface software and plant computer software were developed in Budapest. The control room was modified for the project in the Paks NPP. At the end of 1986 the whole hardware was transported to Helsinki except for the simulation computer system. In NOKIA Electronics the different parts of the system were integrated and in May 1987 the on-line testing and tuning of the simulator was started. The acceptance test of the simulator was carried out in Helsinki during the period of February-April 1988, then the whole hardware system was transported to the Paks NPP. The installation of the hardware at the final location was completed in August 1988 and the simulator was put into commission by the end of 1988.

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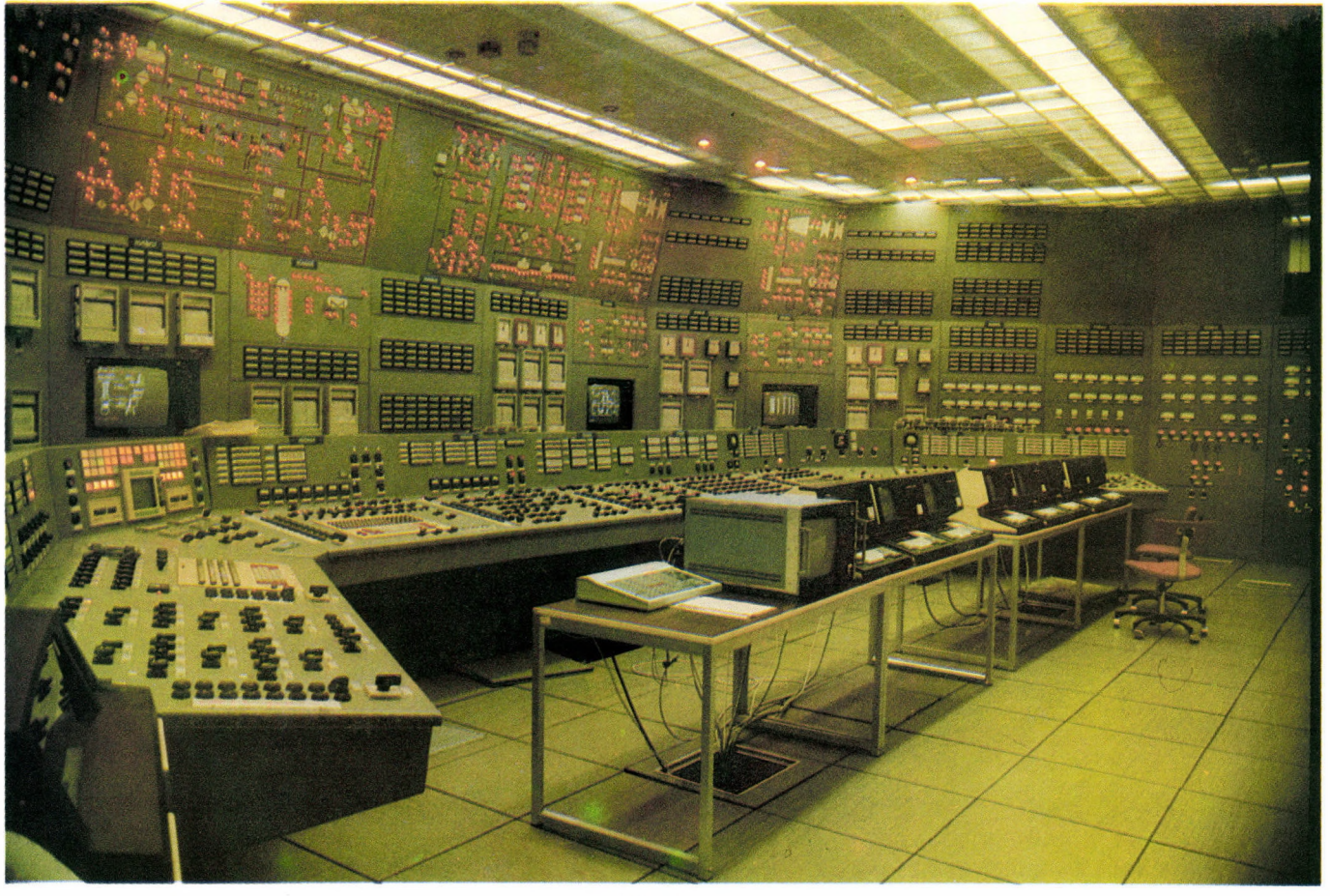

Fig. 4

RECONSTRUCTION AND UPGRADING OF THE RESEARCH REACTOR

The VVR-SM type reactor was in operation for 27 years from 1959 to 1986. The degradation of some components and the increasing demand for new physical research facilities and for extended isotope production have made its reconstruction inevitable.

The main aims of the reconstruction were as follows:

— to replace the degraded parts and to increase flux and power;
— to extend the capacity for isotope production;
— to provide a facility for extended neutron scattering and other research;
— more extensive environmental protection;
— safe and economical operation.

The non-nuclear planning work was carried out by the experts of the ERŐTERV (Power Station and Network Engineering Co.). The nuclear plans, the basic reactor physical and thermal hydraulic calculations as well as the design of radiation protection were developed by the scientists of the AEKI of KFKI. Throughout the reconstruction, engineers of the MSzI of KFKI also contributed to the design, manufacture and installation of various components.

Disassembling the VVR-SM Reactor

The reconstruction was started with the disassembling based on the plans developed by the experts of KFKI. The disassembling activities were done by the workers of the AEKI.

It is worthy of mention that during the 6 months long disassembling period none of the workers' radiation exposure exceeded the dose limit of one month. This fact is of great importance since it was the first reactor disassembled of its kind and there were no experiences of this sort of activity to rely on.

Video-recordings were made about many phases of the dismounting and this can be of great help to other crews that may be engaged in reac tor disassembling. Some video-recordings were made of the construction and mounting phases too.

This reconstruction is aimed at reaching 20 MW thermal power. The reactor is to be operated from October 1989 at the 10 MW level by VVR-SM type fuel assemblies till the new, high power fuel assembly is developed in the USSR. Only the new fuel assemblies will make the operation of the core at the 20 MW level possible.

The name of the new, reconstructed reactor is VVRS-M10.

Main Features of the Reconstruction

In order to achieve the goals of the reconstruction, changing the whole technological and nuclear system was inevitable. To accommodate the 20 MW power the following subsystems had to be changed:

— the core;
— the reactor vessel;
— the dosimetrical system;
— the operational and emergency core cooling circuits of the reactor;
— the electric power distribution network;
— the technological emergency ventilation;
— the radioactive water storage system;
— the high capacity cranes.

We consider as new facilities the following:

— tangential channel;
— cold neutron source and new measuring hall;
— new gate building for the main hall entrance.

With the Chernobyl-accident in mind, a semihermetic main hall and a new emergency air-recirculating ventilation system were built in, to ensure high level environmental protection.

A new Diesel aggregate was set up as a stand-by electric power source in case of an emergency. This aggregate can ensure electric power for the control system and for the cooling and ventilation systems of the shut down reactor should a power failure occur.

Development of the Technical Plans

The nuclear plans were developed and the coupled reactor physical, thermal hydraulic calculations and the radiation protection calculations were made by the staff of AEKI.

In the course of the developing work the plans of the core and its structural design, the reactor vessel, the gravitational emergency core cooling system and the recirculating system of the active water were finalized.

The entire dosimetrical system, the nuclear measuring channels for the reactor operation, the total control and safety system, and the computer aided control network were designed by the staff of KFKI.

The horizontally formed tangential channel, the cold neutron source and the pneumatic rabbit system were also designed by the experts of KFKI. The commissioning test programs of the reactor were developed by AEKI and the actual tests will be performed by its own staff as well.

The non-nuclear plans developed by ERŐTERV were as listed below:

- the operational and emergency core cooling systems;
- the hoisting engines;
- the radioactive water storage pond;
- the technological ventilation systems for normal and emergency situations;
- the accidental air recirculating ventilation system;
- the reconstruction of the buildings;
- the water-processing system;
- the inner construction of the buildings;
- the engineering and electrical network.

The technological development of the semi-finished products and the development of the composition of the reactor-purity aluminium should be emphasized. This was carried out by FKI (Research Institute of Nonferrous Metals) and by the AEKI.

The mechanical strength calculations of the reactor vessel, the core grid, and the base plate holding the vessel were done by the experts of OLAJTERV (Designing and General Contracting Company for the Oil Industry).

The main organizer of this investment was ERBE (Hungarian Company for Power Plant Investment).

Reconstruction of the Main Subsystems

The core

The core at the beginning contains 132, and at the balanced state 223 VVR-SM type fuel assemblies - counted in 'single'.

The neutron moderator is the same light water as used for cooling, and the neutron reflector is a metallic beryllium with an average thickness of 22 cm, which was supplied by the USSR based on Hungarian plans.

In the core there are 3 absorbing rods for safety reasons and another 15 rods for the compensation of reactivity.

The vertical channels for isotope production, and the beryllium reflector containing both the tangential channel and the cold neutron source are also located here.

The ionization chambers of the nuclear control system are situated at the outer part of the core. The maximum diameter of the core is 1 meter.

Cooling circuits

The mechanical devices of primary cooling circuits are situated in the former pumping hall. The high quality pumps and armatures were supplied by the FRG. There was no emergency core cooling system in the old reactor, while the reconstructed reactor is provided with this very important safety system.

The emergency core cooling system is supplemented with a gravitational cooling system, an active water recirculating system which can be activated in case of a vessel leakage, and a water sprinkler device. In the old reactor there were no such emergency safety systems.

The secondary cooling circuit is placed into a new hall equipped with new high capacity pumps and supported by a 20 MW dry type Heller Forgó cooling tower designed and supplied by EGI (Institute for Energetics).

The reactor vessel

The reactor vessel and its inner equipment were produced from reactor purity aluminium developed in Hungary. Its external dimensions are the same as the old vessel's. The vessel is a Hungarian product.

Electric power network

A new energy distribution system and a new emergency power source were necessary to satisfy the greater energy needs. Keeping the idea of dual feeding in mind, a 110 kVA Diesel aggregate unit was set up as safety power source to supplement the highly reliable energy supply, should a simultaneous breakdown in both feeding lines of the country network occur.

Moreover, in addition to these safety systems two 220 V 600 Ah, two other 24 V 360 Ah accumulator units and also two 220 V 40 kW inverter devices ensure trouble-free energy supply.

Technological ventilation system

There are new devices and valves working in the technological ventilation system. To strengthen environmental protection, the air is led through highly effective aerosol and iodine filters into the atmosphere. Also for environmental protection reasons there is an emergency air recirculating system in which there are further aerosol and iodine filters, and the filtered air is recirculated to the closed atmosphere over the reactor water.

An emergency air ventilation device is installed in the technological ventilation system which can be operated from the emergency energy supply.

Reactor control

Of the reconstruction of the control engineering systems (nuclear and technological measurements, control, safety, etc.) the most important aspects were:

- since the original working concept proved to be good, only those modifications were made which were necessary due to the new reactor structure;
- the elements of the degraded old control system were changed to reliable up-to-date (preferably Hungarian) components;
- the new control engineering contains a new, computer aided data processing system but in case of its failure the reactor still remains safely operable.

Controlling the reactor is realized in a new control room, constructed at the site of the former one. In this room the following functional systems are situated - in an extended form:

— the technological gauges with new technological schemes ensuring the easy overview of the correlations, breakdowns and exceedings of limits;
— the nuclear and special gauges which are able to measure directly the reactivity, to sense continuously the wall temperature of fuel elements etc., beside the wider-range measuring of the reactor's nuclear power;
— the dosimetrical instrumentation (see next point below);
— safety logic system, based on an up-to-date PLC (Programmable Logic Control) method with a self-checking capacity using the idea of 2 out of 3 method;
— the units processing the basic information, the signals and inter
— lockings of the electric power supply;
— the control of driving of the control and safety rods;
— the data processor;
— the control panel.

Many other parts and units of the control system are hard to access, and this was taken into consideration at the design phase (e.g. engines and limiters of rod devices).

Dosimetrical instrumentation

The main functions of this system are: to guarantee the radiation safety of the people working in the area and staying in the surroundings of the reactor, and to provide information about the operation of the reactor.

The dosimetrical system includes 88 check-points in the area of the reactor plant and transmits measurement data on:

— the outer gamma radiation level;
— the concentration of radioactive gases and aerosols;
— the gamma activity of the water of the primary and secondary cooling circuit;
— the surface contaminations of the clothes, body and different parts.

Using the Industrial Nuclear Instrument System NFA-01.01 developed by KFKI, the dosimetrical system consists of a 50 channel measuring assembly, supplemented by 2 NK-225 type spectrometers and an RKSZ 2-03 type Soviet radiometer monitoring the emission to the environment. The channels, when sensing radiation levels exceeding the limits, give audible and visible alarms at the site of the measurement and in the central control room.

The radioactive gas and aerosol concentration is measured through a remote-control sampling tube device, taking samples at each individual measuring point.

The data of the environmental emission is also transmitted directly to the computerized environment control center of the Radiation Protection Department supervising the whole area of KFKI.

As a protection against emergency situations, two independent - so called - emergency channels were built into the system which work nonstop, and which are equipped with many output registers.

Extended Research Facilities

The upgrading will improve the conditions for both basic and applied research. Activation analysis laboratories will be modernized, a cooled pneumatic rabbit system will be installed. Irradiation damage investigations will be continued under improved circumstances. An applied research program for non-destructive testing of materials and construction elements by neutron scattering and neutron radiography will be carried out. Fast neutron channels will be used partly for nuclear spectroscopy, partly for biological experiments.

The main research activity will remain neutron scattering, which is a powerful tool for the study of the structure, elementary excitations and phase transitions in condensed matter. For neutron beam experiments different types of horizontal channels have been designed. Seven of the old beam tubes will be kept as radial channels, five of them starting from the Be reflector to give a thermal neutron flux at the exit of about 2×10^9 n/cm^{2}s, while two of them will directly look at the fuel elements to provide a fast neutron flux of about 1.8×10^8 n/cm^{2}s. A new hole will be drilled for a tangential thermal neutron beam, and the former thermal column hole will be used — also in the tangential position — to install a moderator cell to provide cold neutron beams for scattering experiments. Extra Be packing has been designed for the take-off position in the core of these tangential channels to achieve a flux of about 10^{14} n/cm^{2}s. The liquid H_2-moderator introduced horizontally into the thermal column hole will provide cold neutrons taken off by three glass mirror guide tubes. The in-pile part of the guides will be coated by ^{58}Ni. A 14×25 m^2 new building will join the reactor hall to install equipment on the neutron guides.

At the tangential channel a modernized version of the previously used "Edina" two-axes device will be installed (a multidetector will be adapted). It will be used mainly for structural studies of polycristalline, amorphous and partially ordered systems.

One of the channels will be equipped with a dynamic radiography instrument providing process recording in closed volumes by neutron and/or gamma ray transmission. This device will mainly serve for non-destructive industrial investigations. The re-installation of the existing three-axes spectrometer for diffraction and classical inelastic measurements is foreseen on one of the guides. At the end of this guide there will be a cold neutron radiography device, mainly for the high contrast imaging of the inside of metallic objects in the absence of Bragg scattering. High importance is given to the construction of a small angle scattering instrument for structural studies of condensed systems with applications in metallurgy, chemistry, etc.

Extended Volume and Range of Radioisotope Production

In this new reconstructed reactor core and reflector 50 channels serve for activation from which 6 are thermal neutron traps and 1 is for fast neutron irradiation. The capacity of the channels is enough for accepting 200 'standard' irradiation capsules.

The enlarged facilities along with the increase of the usable neutron flux improve the quality of the radioisotopes produced and provide a wide range of new radioisotopes.

Comparison of the Old and the Upgraded Reactors

The main parameters of this reconstructed reactor can be found in the table below — for purposes of comparison the parameters of the old VVR-SM reactor are also given.

Table of reactor parameters

	VVR-SM	VVRS-M10
Load of balanced core (single)	162	223
Thermal neutron flux in the vertical channels ... average	4.5×10^{13} n/cm^{2}s	1.3×10^{14} n/cm^{2}s
maximum	8×10^{13} n/cm^{2}s	2.5×10^{14} n/cm^{2}s
Built-in excess reactivity	5 $	21 $
No. of nuclear channels	7	8
No. of neutron absorber rods	9	18
No. of dosimetrical gauge points	40	88
Neutron moderator	H_2O	H_2O
Neutron reflector	H_2O + Be	Be
Enrichment of the fuel elements	36%	36%
U^{235} content of "single" fuel assembly	40 g	40 g
Maximum flow of the cooling water		
in the primary circuit	760 m^3/h	1740 m^3/h
in the secondary circuit	670 m^3/h	1740 m^3/h
in the emergency circuit	--	100 m^3/h
Maximum temperature after core	60 °C	65 °C
at the secondary circuit side of the heat exchanger	26 °C	50 °C
Maximum heat power		
VVR-S fuel assembly	5 MW	cca. 10 MW
(new type fuel assembly)	--	(20 MW)
No. of irradiation capsules accepted at the same time	100	200
No. of horizontal research channels		
normal	10	8
tangential	1	1
cold neutron	--	1
No. of pneumatic rabbit channels for irradiation	2	3

RESEARCH INSTITUTE FOR PARTICLE AND NUCLEAR PHYSICS (RMKI)

The scientific activity of the Institute covers a wide spectrum of subjects, ranging from problems of cosmic physics and space research to the theory of quantum systems and gravitation theory.

At present, research is conducted primarily in the following areas:

1. cosmic physics and space research
2. experimental particle physics
3. experimental nuclear physics
4. materials science
5. plasma physics
6. biophysics
7. theoretical physics.

The personnel of the Institute includes about 130 scientists, 12-14 postgraduate students and a significant technical staff of highly qualified development engineers and technicians.

Space research and experimental particle physics is conducted in an extensive international collaboration including, as the most important partners, the IKI (Institute for Space Research), Moscow, as well as CERN, Geneva. At present our scientists are involved in the Phobos mission in the field of space research, while in particle physics our team of experts is taking part in the LEP-3 experiment at CERN, Geneva, designed to discover the sixth quark.

Experimental nuclear physics research is conducted both at intermediate energies and cyclotron energies. The mechanism of the collision process is studied in both regions of energy.

Our experimental activity in materials science, biophysics and to some extent also in tokamak physics is centred around the Institute's 5MeV Van de Graaff accelerator, which is now being reconstructed in order to achieve a

much higher stability and energy resolution. Our NIK heavy ion cascade generator, which can be used for implanting a wide range of atoms into materials, when combined with the Van de Graaff accelerator, provides a unique tool for materials science studies using nuclear techniques.

In plasma physics the main item for research is the MT-1 small tokamak device, used primarily in plasma diagnostics studies by means of lasers.

Theoretical physics research is conducted in the main fields of nuclear reaction theory, particle physics and gravitation theory.

The Institute's engineering background has been especially important in our work in space technology, as well as in various applications of electronics. While the Institute's activity is dominated by basic research, in the last years our Technology Department has devoted considerable effort to R+D work in various branches of applied physics.

We hope that the following short description together with a full list of publications will supply the interested reader with the necessary information about the Institute's activity.

Space Research and Cosmic Physics

The wealth of experimental data gathered by the two VEGA spacecraft on their flyby missions to Halley's comet in 1986 has been the main basis for our studies in space research. Following the first analyses after the encounters, further detailed work has recently led to new results in physics of comets and cometary environment.

In collaboration with the Space Research Institute, Moscow,USSR, and the University of Arizona, Tucson, USA, the comet's rotation period and the position of the rotational axis have been determined from the images taken by the VEGA TV system. The nucleus rotates with a period of 2.2 ± .05 days and, owing to the asymmetric shape of the nucleus, its long axis periodically "nods" with a period of 7.4 ± .05 days. Also, a mathematical algorithm has successfully been applied to correct the VEGA-1 images that suffered severe distortion due to the defocussing effect introduced by the CCD's accidental shifting out of the focal plane. In the sharpened images, a number of surface features appear on the nucleus that can be identified on several consecutive frames. To aid the identification process, a new 3-D computer modelling technique has been developed for the fast and flexible generation of a great variety of 3-D shapes, illuminated and viewed from different angles.

The dust-jet radial brightness has been analyzed along jet cores on close encounter VEGA-2 images. It has been shown that the radial brightness distribution has a break-point at about 40 km above the surface of the nucleus. To interpret this result, we propose that dust particles ejected from the surface disintegrate close to the nucleus owing to the heat-shock they have suffered.

For a comprehensive interpretation of the plasma, electric and magnetic field measurements on board the VEGA probes, we compared data obtained from four different instruments near the cometopause that separates two environments with different chemical composition. We have pointed out that fire-hose instability might develop near the cometopause where the number of cometary ions is significantly increased.

The complex intensity-time profiles detected by the energetic particle channels of the TÜNDE instrument have been analyzed and interpreted in terms of the spacecraft's passing through various regions around the comet. An important and intriguing implication of the TÜNDE measurements is the indirect detection of neutrals along the orbit of the spacecraft far from the nucleus. A careful simulation of the trajectories of neutrals including both Keplerian motion and non-gravitational forces has led to the conclusion that neutrals must have a higher velocity than previously assumed.

On the basis of the TÜNDE high energy charged particle measurements on VEGA-1 and 2 during the cruise phase, four recurrences of a particle event associated with a corotating interaction region were detected and interpreted.

The Halley missions inspired theoretical investigations as well. A new model of the cometary atmosphere was worked out in collaboration with the University of Michigan, Ann Arbor, USA. The possibility of first and second order Fermi acceleration of energetic particles in the cometary environment was also examined.

The efforts to explore and better understand the acceleration mechanism of energetic charged particles at interplanetary shock waves is going on in collaboration with the Imperial College, London, U.K. Pitch-angle distributions reconstructed from the measurements of the ISEE-3 spacecraft (now renamed ICE) have been compared with the predictions of the scatter-free model. Results indicate that a scatter-free picture with a simple planar geometry cannot account for the observed sharp intensity spikes. A non planar field configuration, combined with the fluctuation of magnetic field strength and the resulting particle reflection has been proposed as a plausible scenario for producing these spikes.

The power spectrum of intensity fluctuations of cosmic rays in the 4 to 200 GV range has been investigated in a cooperative project with the Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Czechoslovakia.

In a joint project with the University of Arizona, Tucson, USA, a new 3-dimensional numerical code has been developed to solve the transport-equation of cosmic rays in the heliosphere, including all known physical processes: diffusion, convection, drift, adiabatic cooling, and shock-acceleration. The major development with respect to the earlier 3-D model is that the new code employs a dynamical solar wind model which takes into "consideration" the observed increase of the solar wind speed away from the heliospheric neutral sheet. Also the polar heliospheric field has been revised: instead of the rapidly falling radial field, the polar field should be dominated by the random transverse component. The first numerical results indicate that the model correctly predicts the evolution of the latitudinal cosmic ray gradient as the 22-year solar cycle proceeds.

Implications of recent observations of very high energy gamma rays arriving from accreting pulsars have been studied in collaboration with the Astronomy Department of Pennsylvania State University, USA. A simple model has been proposed for the acceleration of protons near the corotation radius of the pulsar magnetosphere, and for the subsequent generation of TeV and possibly PeV gamma rays. It has been argued that the main acceleration process should take place in shocks formed between the accretion flow and a jet emerging from the polar cap region of the pulsar.

Several aspects of the recently proposed fifth force have been examined. Claims by American scientists for the existence of this new fundamental force were based on the reinterpretation of the Eötvös experiment performed in Hungary 80 years ago. In our institute, the circumstances of the Eötvös experiment have been examined in some detail by using archival material. A thorough analysis of the results of a similar experiment performed 25 years later by J. Renner in Budapest has been shown to contradict the above claims. A new experiment similar to those of Eötvös and Renner has been started in a cave of the Buda Hills in order to clarify the situation. No indication of the existence of a fifth force has been found so far in this experiment, which is a collaborative effort between our institute and the Eötvös Loránd Geophysical Institute, Budapest. The results of the investigations have been presented in several lectures and seminars both in Hungary and abroad.

The most recent activities in space research are centred around the PHOBOS missions launched by the USSR in July 1988. Instruments have been built and experiments are being carried out in broad international cooperation. Hungarian scientists are primarily involved in the ESTER measuring complex, which consists of three particle instruments. The Low Energy Telescope (LET) constructed by ESA detects the flux, spectra, and elemental composition of nuclei up to iron in the energy range 1 MeV/n to 75 MeV/n. The SLED detector systems built by St. Patrick College, Maynooth, Ireland, monitor electron and ion fluxes in selected channels within an energy range of several tens of keV to a few MeV. The HARP device is an electrostatic analyzer built in our institute.

It is designed to detect both ions and electrons starting from a very low threshold energy (below I MeV) with a good energy and moderate directional resolution. This experiment is a collaborative effort involving the University of Michigan, Ann Arbor, USA, and IKI, Moscow, as well. Planned to be active throughout the mission, HARP is primarily intended for measurements in the Mars environment. Our scientists also participate in experiments measuring the properties of the solar wind (SOWICOMS, TAUS).

At the time of writing this report the data obtained in the cruise phase are being analyzed and preparations for the Mars encounter early in February 1989 are in progress.

Experimental Particle Physics

Groups formed in the Particle Physics Department take part in various worldwide, international collaborations. Simultaneously, research is being conducted into a phenomenological understanding of the experimental data.

We are involved in the L3 collaboration whose aim is to study electron-positron annihilation in the 90-200 GeV c.m.s. energy range at the world's largest electron-positron storage ring under construction at CERN.

The construction and installation of the L3 detector is in progress, and on schedule. The detector is being designed to measure the energy and position of leptons with high precision allowing a mass resolution smaller than 2% in dilepton final states. The hadronic energy flux will also be measured with considerable accuracy.

The Budapest group has made significant contributions to the off-line software system of the experiment. The group has performed optimization studies by Monte-Carlo method and it has participated in the calibration of the detector elements as well.

One of our groups has been taking part in the European Muon Collaboration (EMC), which studies the structure of the nucleon and the nucleus, and the hadron production in deep inelastic muon nucleon scattering by using the high quality muon beam at the SPS of CERN. The gathering of data was finished in 1985. Since then, we have been focussing on the physics analysis of the available information.

The neutron structure function along with the momentum and charge distribution of quarks inside the nucleons were extracted. Several points of evidence of a difference between free and bound nucleons were found including structure function ratios for different targets and the shadowing effect.

An extensive study of the hadronic final states has been continued. Retention of quark charge by fast hadrons and local charge compensation have been observed. Hadron jet formation, angular distribution of final state hadrons, as well as strange particle and proton production were found to be consistent with the basic ideas of the quark-parton model including QCD effects.

In the European Hybrid Spectrometer (EHS) experiment, investigation of the soft hadronic process in pp collisions at 360 GeV/c was continued. Our Lund based fragmentation model including quark-diquark systems combined with a simple geometrical model describe fairly well the measured elastic, inelastic and diffractive dissociation differential cross sections.

The partial agreement between the results of model studies of correlation problems and the experimental data suggest the importance of QCD effects in the fragmentation process, the introduction of more chains and the consideration of cluster formation.

Our understanding of hadronic final states in proton-nucleus (Al,Au) collisions at the above energy may contribute to the study of the quark-gluon plasma formation in high energy ion-nucleus collisions.

We organized the 2nd Common EHS Collaboration Meeting in Tihany, in September 1987. More than 40 scientists from the SU and Western countries took part in the five-day workshop.

Direct photon and pi zero production has been studied in hadron-hadron collisions at 300 GeV/c (NA 24 collaboration).

Detailed study of hadronic final states in nucleus-nucleus collisions at 200 GeV/nucleon has been performed (NA 35 collaboration).

We are also involved in the Dubna-Serpukhov based RISK Collaboration. The experiment was carried out with the RISK streamer chamber spectrometer using a negative pion-beam of 40 GeV/c and a trigger requiring a secondary charged particle with transverse momentum above 1 GeV/c. Different nuclear targets were placed inside the chamber. We took part in the irradiation, in the measurements, in the compilation of DST as well as in the physics interpretation of events. The comparison of the results obtained recently for H and D targets with those obtained earlier for C,Cu,Pb targets stresses the role of the multiple scattering inside the nucleus. This assumption is supported by the increase of the multiplicities and of the number of slow secondary protons in terms of atomic mass, as well as by a comparison with the low P_t data. In the c.m. system of the negative pion-N the K^os and antilambda are produced centrally and the lambdas come mainly from target fragmentation. It is remarkable that the probability of antilambda production with high P_t trigger is about twice that obtained for the no trigger events. The other strange particle production does not show similar properties.

In the Dubna-Serpukhov-Berlin-Budapest collaboration the measurements started with the neutrino calorimeter at the Serpukhov accelerator. A program system for the reconstruction of events has been adopted.

We are also involved in the neutrino experiment on Lake Baikal. A Monte-Carlo simulation of the experimental set-up is being performed there and our group is also active in the measurement process.

Based on our phenomenological studies, we propose a distribution function for multiplicities of different processes in accordance with the stochastic number evolution. The same function can also be extracted from a generalized geometrical model in the impact parameter representation. Our function gives a general description of inelastic and nondiffractive multiplicity distributions in pp collisions. A remarkably good agreement was found between model and experiment concerning in respect of the higher scaled moments and the multiplicity distributions of e^+e^- annihilation into hadrons.

A new analytical method was developed for restoring the 2-π inclusive distribution from observed bubble chamber data. An exponential asymptotical behaviour for π^o π^o relative rapidity distribution has been established.

Experimental Nuclear Physics

The mechanism of intermediate energy nuclear reactions is still the subject of extensive research. Inclusive production and quasi-free processes are of particular interest. The study of particle production by 300-550 MeV neutrons was continued in cooperation with a team from Freiburg University, FRG. To obtain the dependence on target mass the experiments were extended to include the nuclei Cu and Bi. The energy spectra of protons, deuterons and tritons were measured in the angular range from 54° to 164°. The data were analyzed in terms of the quasi two-body scaling model. In contrast with the case of the carbon results, the scaling behaviour was found to be rather poor for these nuclei. Energy spectra of charged pions were also measured and fairly well understood in terms of the cascade model.

The exclusive proton-deuteron break up reaction pD→ppn has been studied at 1 GeV at the Leningrad Institute of Nuclear Physics. Differential cross sections have been measured in the range of the neutron-spectator momenta $0 < k < 0.3$ GeV/c, and the polarization of he final protons between $0 < k < 0.2$ GeV/c neutron spectator momenta. The data obtained are well described within the framework of an impulse approximation with the Paris wave function of the deuteron.

A coincidence experiment with polarized deuterons was started at the Laboratoire National Saturne (Saclay) in a Leningrad-Saclay-Budapest collaboration to investigate the deuteron wave function at large internal momenta by means of polarized dp→ppn reaction.

Within the framework of a collaboration with the CEN-Saclay, the charged particle emission was analyzed in p+Cu collisions in order to be compared with n+Cu reactions, using the data measured by the DIOGENE 4π detector.

The experimental investigation of intermediate energy heavy-ion reactions has been performed in a joint effort with Eötvös Loránd University, Budapest, and Michigan State University, USA. The mechanism of neutron emission was studied. A new method of the sequential neutron decay spectroscopy was worked out and used for deriving nuclear temperatures in nucleus-nucleus collisions, and measuring excitation dependence of projectile like fragments on their kinetic energy. An example of the results is given in Fig. 1.

Further efforts were made in the standardization of the ^{252}Cf spontaneous fission neutron spectrum in collaboration with the IPPE, Obninsk, USSR. More refined Monte-Carlo calculations were carried out to determine the efficiency of a thick ^{6}Li glass detector. In cooperation with the TU Dresden, GDR., the angular distribution of ^{252}Cf fission neutrons was measured in the angular range of 0°-180°, with an improved angular resolution of 6.5°, using a newly developed TOF spectrometer.

Studies on the fragmentation of 1g9/2 isobar analog resonances have been continued in cooperation with the Tandem Accelerator Laboratory of McMaster University, Hamilton, Canada and Universite Laval, Quebec City, Canada. In ^{61}Cu eleven, ^{53}Mn twenty-four fragments of the 1g9/2 isobaric analog state have been found, studying the ^{60}Ni(p,p$_1\gamma$, ^{60}Ni(p,γ)^{61}Cu and ^{52}Cr(p,p$_1\gamma$), ^{52}Cr(p,p$_2\gamma$), ^{52}Cr(p,γ)^{53}Mn reactions. Excitation functions were measured in 3.67-3.83 MeV and 4.04-4.35 MeV proton energy range. The excitation function in (p,p$_2\gamma$) reaction is a sensitive tool for locating resonances with higher ($5/2 < J_R < 13/2$) spins and it helped to select the candidates for 1g9/2 resonance fragments. The spins of the resonances were assigned from the analysis of the gamma angular distribution measurements. Partial widths for each resonance fragment were deduced and fine structure analyses were carried out in the different channels. The inelastic spectroscopic factor for the 1g9/2 isobaric analog state was derived.

In collaboration with TRIUMF, Vancouver, Canada, the angular and energy dependence of neutral pion production was investigated in the scattering of polarized protons on hydrogen near the energy threshold, in the range of 300-500 MeV. Differential and total cross sections and analyzing powers were extracted. Also at TRIUMF, negative muons were stopped in gaseous mixtures

of hydrogen and deuterium and in HD gas and the photons and neutrons from the muon-induced fusion reactions were counted. The temperature dependence observed is in sharp contradiction with the theoretical predictions.

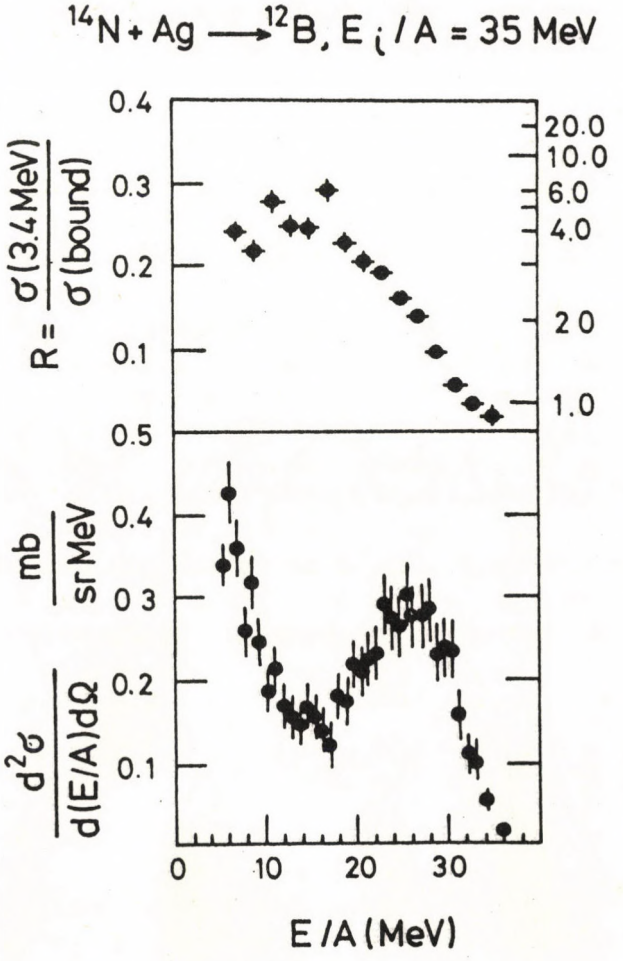

Fig. 1

The spectra of neutron multiplicity through the sequential decay of the 3.4 MeV energy unbound particle state (above) and kinetic energy (below) of ^{12}B fragments measured at 15° (lab) from the reaction $^{14}N+^{107}Ag$ at E/A=35 MeV energy.

Radiative formation and decay of hyperons were studied at the slow-kaon beam of the Alternating Gradient Synchrotron of Brookhaven National Laboratory. The Σ^o and Λ hyperons were observed after the decay of the

kaonic hydrogen atom and the branching ratios were determined. We also measured the branching ratios of the kaon radiative capture in deuterium and of the weak radiative decay of the Σ^+ hyperon. A second phase of the experiment is aimed at studying the weak radiative decay of the Λ hyperon. For that we installed the Los Alamos Crystal Box consisting of 396 NaI segments and had two data collection runs.

Materials Science

In approaching the irradiation problem we will have to face in future D-T burning reactors we have studied the effect of temperature on surface modification and trapping/reemission behaviour of Al and AlMgSi alloys during MeV energy He implantation and post irradiation annealing. For the applied implantation energies (0.6-3.5 MeV) and temperature range (R.T.- 825 K) blistering or exfoliation, but no porous structure has been observed on the implanted area. The peak He concentrations corresponding to critical doses for the onset of surface deformations are in strong correlation with the tensile strength of the target materials. While at R.T., they have a constant value (33 at.% for Al and 48 at.% for AlMgSi), independently of the bombarding energy, at elevated temperatures they decrease in accordance with the temperature dependence of tensile strength. During post-irradiation annealing He is released in two stages. First at the onset of blistering or exfoliation, showing that the release originates from the volume under the detaching layers. The second stage occurs at temperatures around 780 K in both materials.

The stress model describing the regular wave patterns observed after flaking on certain high dose ion implanted materials has been tested using quasi-simultaneous multiple energy irradiation. We found that the proposed relationship between the characteristic wavelength and the ion range straggling still works, despite the one order of magnitude change in the wavelength.

The method of Elastic Recoil Detection was considerably improved. The non-Rutherfordian differential cross section for H in the case of alpha particle bombardment was measured in the 0.9-3.4 MeV energy and 16-41 recoil angle range. Determination of the recoil cross section was made possible by working with the optimum of the probing depth and the depth resolution. Knowing the differential cross section and the stopping factor, the measured spectra can be converted into concentration vs. depth profiles. The depth distribution of hydrogen isotopes was determined by ERD in amorphous silicon, silicon nitride and silicon oxide samples.

Positron annihilation lifetime studies were performed as a contribution to the research activities at ZfK Rossendorf, GDR on neutron irradiated reactor pressure vessel steels. The first results of the annealing studies concerning

the influence of irradiation temperature, flux of fast neutrons as well as different impurity contents of steels were already presented and discussed. For the first time, possibility of explaining the positron annihilation data by irradiation induced carbide formation were proposed, but further investigations are necessary to clarify this point.

The long-lived non-equilibrium population of the Zeeman sublevels of the ^6S ground state of Fe^{3+} ions after the electron capture of ^{57}Co in various trigonal single crystals has been further analyzed in collaboration with the universities of Erlangen and Mainz. The temperature dependence of the Mössbauer emission spectra of ^{57}Co in $LiNbO_3$ revealed that relaxation of the anomalous population should take place in the lowest lying Kramers doublet of the first excited manifold of Fe^{3+}.

Plasma Physics

The research is concentrated around the MT-1 small size tokamak. (Major radius R_0=0.4m; minor radius a=0.09m; toroidal field $B_{t\ max}$=2T; current I_{max}=35 kA and the duration of the discharge τ=9 msec.)

In the following we will present some of the topics we investigated, and some of the results we obtained in the last two years.

1. Tokamak edge plasma physics

The edge plasma density distribution and the transport of the blow-off injected alkaline impurities have been investigated in the MT-1 tokamak plasma using visible spectroscopy of the edge region, erosion and deposition probes, Langmuir probes, and a movable instrumented limiter. (see Fig.2.)

The characteristics of the laser blow-off atomic beam (density, velocity distribution vs. laser irradiance of the blow-off target) is being investigated separately from the tokamak with a special measuring set up.

Sodium atoms were injected into the edge plasma of the MT 1 tokamak by laser blow-off. By changing the laser irradiance at the thin film of sodium the velocity distribution of the blow-off burst of atoms was tailored so that the atoms excited by the plasma electrons in the edge region emit an about hundred μsec light pulse.

A low velocity atom is ionised within a shorter distance than a high velocity one is. Therefore, the observed duration of the light pulse emitted by the burst of atoms decreases with decreasing plasma radius at a rate wich is proportional to the line integral of the plasma density along the propagation of the atoms. Consequently, measuring the duration of the light pulse at different

plasma radii, the density vs. plasma radius function can be calculated. The observed density distribution can be described by a parabolical function of the plasma radius, in agreement with the result of the density measurement performed by microwave interferometer.

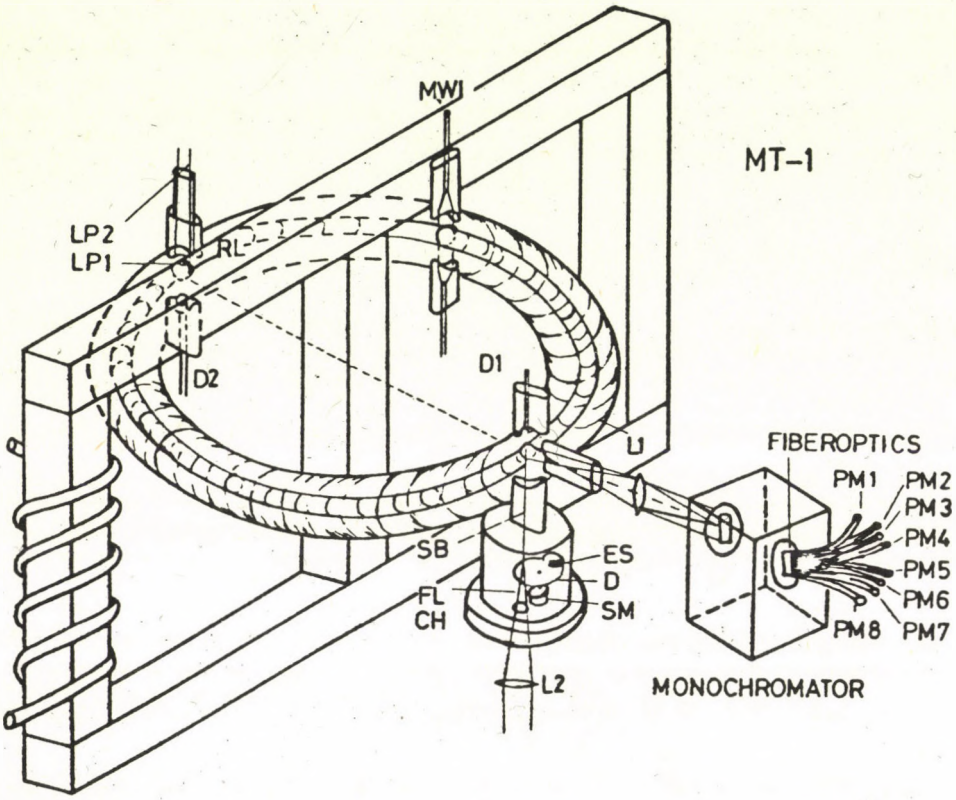

Fig. 2

Experimental set-up for the investigaton of the edge plasma of the MT-1 tokamak. LP1 and LP2 are Langmuir probes; D2 and D1 are double erosion and collector probes; MWI is a microwave interferometer, CH is the laser blow-off assembly, where SB, FL, ES, D, SM are the laser blow-off neutral beam, ruby laser beam, Na evaporation source, glass disk and stepping motor. L1-L2, PM1-PM8 are lenses and photomultipliers.

Using the above density distribution and the result of the velocity distribution measurement obtained by a separate measuring set-up the ion deposition profile of the injected impurity could be calculated and was found to be inside the limiter radius. Consequently, the main transport of the atoms proceeds in the direction of the plasma center with consecutive ionization to a higher and higher degree and — afterwards — the effusion of the multiply

ionized ions into the scrape-off layer of the plasma takes place. Getting to the scrape-off layer these ions are accelerated into the direction of the limiter, where they are implanted into the neutralising plate and thus disappear. By observing the intensity of the resonance light of the impurity atoms in the limiter chamber both the decay of the impurity content of the plasma due to the cross diffusion and the diffusion coefficient can be determined.

The cross diffusion coefficient can also be determined by measuring the exponential distribution of the density of the impurities and plasma ions in the scrape off layer. This measurement can be performed by using deposition probe where the impurity ions are implanted. The density of the implanted ions is measured post mortem by using nuclear analytical methods (as RBS, SIMS). The cross diffusion coefficient can be calculated from the measured e-folding length if the parallel velocity in the scrape-off layer is known. By using the value of the cross diffusion coefficient calculated from the earlier impurity confinement time measurement the parallel velocity was found to coincide with the ion sound speed for the plasma ions, independently of the sort of the investigated impurity. This suggests strong coupling between the transport processes of atoms of different sort.

2. Plasma MHD activity and disruption investigations

The perturbations in the smooth bell-shaped distribution of the current density cause the appearance of magnetic islands in the magnetic field topology. Because of the rotation of the plasma these magnetic features induce a signal in the magnetic probes positioned around the plasma column. The rotating magnetic island can also be detected by observing the intensity of the soft x-ray radiation along a chord.

The redistribution of the magnetic configuration leads to the anomalous transport of heat and to the corresponding cooling of the plasma. The growing activity of magnetic island formation causes the redistribution of the magnetic configuration, the increasing heat transport and consequently the temporal decrease of current as well as the increasing loop voltage. All the effects are consequences of minor disruptions.

The magnetic island formation and the minor disruption are investigated on the MT-1 tokamak using home developed soft x-ray pinhole cameras of different construction, magnetic probes and neutral particle analyzer.

The MHD activity and magnetic island formation have been observed near the density limit of the tokamak discharge using soft X-ray pinhole camera, multichannel neutral beam energy analyzer, visible spectroscopy and Mirnov's coils. Minor disruptions were observed the signature of which is visible on every diagnostic signal (see Fig.3). The minor periodic disruptions

are preceded by 2/1 mode activity, due to the magnetic island formation. The density limit has also been investigated. Major disruptions have been observed at q_a values smaller than 3.

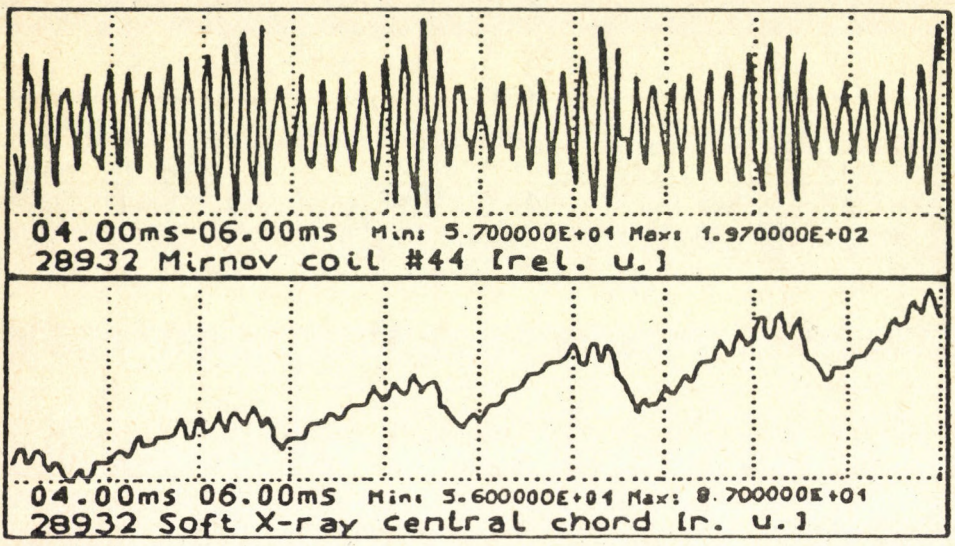

Fig. 3

Diagnostic signals of the MT-1 tokamak plasma soft disruption in dependence on time. The upper part of the figure shows the signal of a magnetic probe while the lower part presents the signal of the soft x ray detector viewing along the chord through the centre of the plasma column. The periodic variation is the consequence of the rotating magnetic island, while the sawtooth-like signature refers to the minor disruption. The correlation of the two signals is remarkable.

Particle and radiation emission is analyzed during periodic disruption. High energy (over KeV) and high flux atomic hydrogen emission was observed during the instabilities, though the central ion temperature was only about 100 eV.

3. Plasma- wall interactions

In future thermonuclear reactors MeV energy He ions will hit the first wall of the device while energetic neutrons will also cause radiation damage. Therefore, investigations have been made in this field to clear up the extent of the expected radiation damage.

He ions in the 0.8-3.5 Mev energy range were implanted in various polycrystalline materials as well as in single crystal silicon wafers and amorphous metalic glasses. The layer above the projected range flaked off or blistered depending on the implantation energy and sample temperature. In several experiments the He rich zone of the exfoliated layer and the remaining bulk material suffered secondary surface deformations of a similar kind. In certain cases the induced high lateral stresses caused a regular periodic rippling of the implanted layer in homogeneous materials. Implantations with wide energy distributions showed that the detaching process was initiated at the depth of maximal He concentration. In order to model the effects of simultaneous radiation damage Ne and Ar ions of 0.7 and 1.4 Mev energy were also applied in separate experiments. In these cases the rippling of the implanted layer could be detected right on the target surface. Cylindrical blisters also appeared on single crystal Si. Radiation enhanced and stress oriented material transport is expected to play an important role in these phenomena.

4. Far infrared laser physics

A method which is based on the observation of the interference fringes in a Michelson interferometer is developed for measuring the complex index of refraction of new polymer materials as Templen produced in the Soviet Union. The measurements are performed in the 70μm and 337μm wavelength range using different optically pumped far infrared lasers developed in the Institute and a discharge pumped HCN laser. The new material shows the same index of refraction in the visible and the FIR region of the spectrum but a smaller absorption coefficient than a similar material, TPX, used generally up to this time.

5. Resonance ionization spectroscopy analysis

A sensitive method for the determination of the trace impurity content of thin surface layers ion implanted in the process of the high temperature plasma wall interaction is being developed using the method of the resonance ionization spectroscopy (RIS). Investigation of the particle transport of intrinsic and nonintrinsic impurities is being contemplated in the SOL of the tokamak plasma to clear up the structure of the plasma periphery. We also plan to study structure damage and structure change due to hot temperature plasma by using RIS.

Biophysics

The accelerator based nuclear analytical activity has been successfully continued. Our PAGE-PIXE method, in collaboration with the Biological Research Centre, Szeged, was extensively used to measure the Fe and Ni content of hydrogenase enzymes of different origin. Within another cooperation with the Szent Györgyi Medical University, Szeged, PIXE measurements of single hairs are continuously monitoring the trace element metabolism of children with dietary illness. The so called ionacoustic effect, an analog of the photoacoustic one, was demonstrated using 1-3 MeV proton and alpha particle beams. The acoustic signals were detected by a microphone mounted in rear gas-cell geometry and their behaviour was well desribed by the heat wave theory.

The photocycle and the corresponding electric signals from vacuum-dried bacteriorhodopsin were studied by flashes from a nitrogen laser drived dye-laser. The analysis of the electric signals has shown that under these dehydrated conditions the protons did not leave the membrane. Only a backward and forward motion with respect to the proton-pumping direction of the bacteriorhodopsin took place.

The experimental study of the neural network formation has been continued. The many electrode culture chamber system was further improved. A new, more compact, printed microelectrode circuit was developed in collaboration with the Research Institute for Microelectronics. CNS and DRG neurons were succesfully cultured on this new system and the pace-maker activity of the cells were observed in cooperation with the Eötvös University, Budapest, and the Medical University of Grenoble. Our efforts to stimulate the neuron networks and to detect their electric response led to encouraging preliminary results.

The theoretical neurobiological research was mainly motivated by the challenge to find what brain theory could offer to engineers for designing near-future-generation computer systems. Dynamic connections among cortical modules, topographic mapping between neural populations, the limits to specificity of neural wiring, the role of randomness and gene-saving mechanisms during ordered neural structure formation, the existence of common mechanisms for normal ontogenetic development and plastic behaviour, the occurence of controlled rhythmic temporal patterns give the evidence that self-organization is the very essence of neural organization. Brain-like machines might be operated by similar self-organizing mechanisms. The scope and limits of the ultrametric structure of semantic memory has also been analysed. Several artificial neural network classifiers were compared for precision. It was found that in decreasing order the Boltzman Machine,

Learning Vector Quantization and Back Propagation algorithms can approach the theoretical limit. It also turned out that the most precise Boltzman Machine is far the slowest approach.

Theoretical Nuclear and Particle Physics, Gravitation Theory

In nonrelativistic nuclear physics, which is one of our research fields of the longest tradition, multiparticle scattering theory offers a full dynamical description of quantum systems. The application of the exact formalism to actual problems is, however, by no means a trivial task. Physical intuition is still expected to play an important role in introducing reliable approximation schemes, or in constructing few-body models of realistic value for multiparticle processes. In our actual investigations, the polarization effects were studied in the three-nucleon breakup process by means of the Faddeev formalism. A simple three-body model of the muon catalyzed fusion process has been constructed. Furthermore, various approximation schemes of the conventional nuclear reaction theory have been reinvestigated on the basis of exact scattering theory.

In potential scattering, the Born series has been generalized by developing absolute convergent expansions of the fully-off-the-energy-shell matrix elements of the transition operator. Furthermore, the turning-point singularities, typical of the standard WKB approach, could completely be eliminated by working close to and far off the origin with two different strengths of the centrifugal terms. Also, for each nonintegrable scattering problem an integrable cut-off problem has been found.

In the field of relativistic heavy ion physics, a successful team studied the problems of formation and rehadronization of the quark gluon plasma in the framework of statistical physics, thermodynamics and hydrodynamics. For the description of the very dense and hot matter formed in heavy ion collisions we have developed various approaches implying relativistic mean field models, string models and hydrodynamical methods.

In elementary particle theory, earlier experience in the field of gauge theories allowed us to follow the latest developments, in particular the string approach to the unification of the fundamental interactions. Among the numerous problems about string theories, methods of classifying the consistent string models have been studied. A general scheme has been elaborated for the classification of heterotic string models for even number of space-time dimensions. The procedure was applied to the 8-dimensional case. Higher level Kac-Moody representations have been used in an attempt to reduce the

rank — the number of gauge interactions — of the gauge groups in string approach. The results obtained in QCD and a study of the consequences of the possible existence of a fifth fundamental force are also worth mentioning.

Intensive activity has been devoted to the field of quantum theory of measurement. A novel gravitational theory for solving the problem of reduction of wave function has been presented. Several related issues (e.g. those of quantumstochastic processes, continuous quantum measurements) have been investigated.

In general relativity, investigations on the gravitational collapse, the final state of axisymmetric sources and on relativistic causality have been the issues. For the non-rotating gravitational collapse, described by the Robinson-Trautman theory, the asymptotic final state has been shown to be the radiation filled Vaidya universe.

In the theory of relativistic causality, research has been focussed on the problem of how to attach boundary points to space time so as to be able to discern between singular points and points at infinity. Two successful attempts at the definition of boundary of space time emerged. Both are refinements of the Geroch-Kronheimer-Penrose theory based on terminal irreducible chronological sets.

In quantum gravity, the development of a spin coefficient approach to topologically massive gauge fields is worth mentioning.

Engineering Background

The engineering background required for the experimental research work at the institute is provided by the Technical Department. The technical expertise and knowledge obtained in this field is also utilized in specific cooperations with other research institutes both in Hungary and abroad in applied research or in industrial applications.

The traditional field of electronics development in the department is nuclear electronics. Some new modules have been added to the existing Camac instrument family. The design of a 64 kword and of a more versatile 32 kword analyzer memory module has been completed. Both modules can receive data from several nuclear analog-to-digital converters thus permitting simultaneous high speed acquisition of nuclear spectra. The 32 kword version has been constructed with CMOS memory chips with battery back-up. A new high voltage power supply was also developed in Camac. It features 0 V to 6 kV output voltage, max. 6 mA output current, low noise and high stability.

For scintillation detector measurements a new microprocessor controlled nuclear spectrometer was developed. The instrument consists of an amplifier-discriminator, a high voltage unit, a timer-counter and a digital data

output unit. With the help of a standard matrix printer the measurement data can either be printed or plotted in graphic mode. The spectrometer can also be connected to personal computers via an RS 232C line. As an option, a spectrum stabilizer board can be inserted into the instrument to facilitate long duration, high stability measurements.

In connection with the reconstruction of the MT-1 tokamak a new electronics system was built for the plasma beam stabilizing system, based on Soviet documentation.

The prototype of an iodine monitor unit, designed for use in the new environmental monitoring system of the Paks Nuclear Power Plant, was built and successfully tested. The instrument counts pulses coming from four GM tubes and measures the amplitude of pulses of a scintillation detector. To ensure long term stability and to compensate for gain changes caused by extreme temperature variations the unit contains a spectrum stabilizer.

For high resolution gamma spectroscopy measurements a microprocessor controlled multichannel analyzer board was designed for use in IBM or compatible personal computers. The unit features 4 k resolution, variable discrimination level, coincidence or anticoincidence gating, time and count presets, selectable region of interest and 2x4 k by 23 bit data memory, permitting the collection of gated and non-gated spectra simultaneously. Once the measurement parameters have been set and data collection has been started, the unit does not require any attention of the computer and the PC can be used for other purposes. The user-friendly software makes the use of the board convenient also for people with no experience in programming and it makes possible the further processing of measurement data.

The participation in various space research programs has played a significant role in the activity of the department. In the framework of the Intercosmos program the development of the plasma analyzer system and of the on-board computer of the unit to land on the surface of Phobos was successfully completed. The space probes carrying the instruments were launched in the direction of Mars in July 1988.

Of the many experiments flying on the Phobos spacecraft the ESTER plasma analyzer was developed in a cooperation between the USA, Austria, ESA (West European Space Agency), Ireland, Hungary, FRG and the Soviet Union. The system contains three detectors: LET measures relatively high energy particles (mainly cosmic rays), SLED measures the energy and spatial distribution of intermediate energy particles of solar and interplanetary origin, and HARP does the same for very low energy charged particles (solar wind and suprathermal particles).

The on-board computer of the lander not only controls scientific experiments, processes their data and transmits them to Earth but it also performs control of the complete probe. The computer is an 8 bit, high

reliability, low consumption double system (the combination of cold and warm reserves) ensuring continuous operation without loss of the integrated measurement data.

The development of the new 16 bit on board computer of the Mars probe to be launched in 1994 has begun. It is intended to control the camera of the orbital unit and the operation of a vehicle roving on the surface of Mars.

Image processing is gaining greater and greater importance in various fields of science and technology. The design of the color graphic display unit developed earlier has been improved. The field of application of the system was extended and the installation work continued.

The image processing system designed to analyze the pictures taken of comet Halley in the VEGA mission was further developed and the related software was completed. Processing of the pictures is going on. The preliminary results were presented at several conferences (Toulouse, Heidelberg). The construction of the MICROSVIT image processing system to be installed on board the Mir space station has begun.

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RESEARCH INSTITUTE FOR SOLID STATE PHYSICS (SZFKI)

During the years 1987-88 this Institute dealt successfully with its traditional activities both in basic research and in applied R & D topics.

Research covered four main areas:

1. lasers and light spectroscopy
2. theoretical solid state physics
3. metal physics
4. partially ordered condensed matter.

The success of basic research is indicated by the attached publication list containing about three hundred titles.

Work in research and development includes a wide variety of activities: it starts from engineering work in applied electronics and equipment design (e.g. electromagnetic non-destructive testing); it continues with the technology of metallic glass production and the various applications, and progresses to the development of laser systems for industrial and medical applications.

One of the characteristic features of these activities is the tight link between basic and applied research.

Following a general review of the progress achieved in the traditional fields of SzFKI, some important selected topics will be described in more detail.

Development and Research of Lasers

In the field of high intensity "laser light — matter" interactions the time-of-flight energy analysis of the electrons created by linear (excimer laser irradiation) and multiphoton (Nd laser irradiation) photoelectric effects of solid metal targets revealed a new character of electron energy distribution. Contrary to the simple theoretical predictions, we observed photoelectrons with unexpectedly high energy. This phenomenon is closely related to "above threshold ionization" which has been observed in atoms already, but many of the details remain unclarified as yet. A huge number of photoelectrons were created on a metal surface by using ultraviolet photons of an excimer laser beam.This method may be applied as:

— cathode source for pulsed electron accelerators and
— cathode source for free-electron lasers

having hundreds of A/cm^2 currents and 17^o-20^o divergencies.

The nonlinear change of refractive index in saturable dye operating in a resonator produced by the actual laser pulses of the mode locking laser itself was studied. The examined self-aberrational ring structure has strong effects on the operation of the mode-locking lasers.

As in our earlier experiments for X-ray emission, we found recently that the intensity of the UV emission may be increased by several orders of magnitude by applying a strong external electromagnetic field to the laser created plasma. This effect is promising in both UV and X-ray laser research.

As an organic completion of the basic scientific topics, we investigated the laser produced plasma spectra of known composition targets. In these experiments — supported by the National Committee for Technological Development (OMFB) — we used a MP-Q-003 Nd: phosphate glass minilaser developed by our group, and searched for the possibilities of its practical application. Combining this new laser with a simple optical multichannel analyser, we proved the development possibility of a laser plasma spectrometer useful for analytical purposes.

Exciting the He-Ar, He-Kr and He-Ne-Xe noble gas mixture hollow cathode lasers by 400 μs duration current pulses, two peaks were observed in the laser output pulse, one occurring at the beginning, the other occurring at the end of the pulse. The first peak in laser power was explained by an increase in the density of the ground state lasing ions, while the second is caused by a fast decrease of lower level population. A peak output power of 120 mW was observed in the He-Kr laser.

The line broadening of the spontaneous 469.4 nm transition of the Kr ion was investigated and it was found that the Doppler broadening is 1.1 GHz, while the collision broadened Lorentz width amounted to 0.7 GHz. The high value of the latter is considered to be the reason for the single mode operation observed in all three noble gas mixture laser systems.

The gas discharge processes influencing the intensity and spectral line shape of hollow cathode lamps used for atomic absorption measurements were investigated in detail. In order to increase the lamp intensity without spoiling the spectral line shape a hollow cathode lamp of new construction was developed. In this lamp, the unexcited copper atoms are driven into the main discharge region by cataphoresis. Thus an order of magnitude intensity increase with an appropriate spectral line shape can be reached on the 324.7 nm resonance line of a copper hollow cathode lamp.

Laser Applications

Our physicists invest substantial effort also in applying the results obtained in the course of their research work. They take an active part in the common project of the Hungarian Academy of Sciences and the Soviet Academy of Sciences in developing solid state lasers.

The group engaged in developing solid state lasers has continued to improve the Nd:YAG (crystalline and glassy) lasers. This group works in Soviet-Hungarian cooperation in laser development, which is discussed elsewhere in the present book.

In the optical thin film laboratory the vacuum evaporation system was provided with an in situ optical monitoring system and a high power electron beam evaporation source, which opened the way for the development of numerous new types of optical coatings. Some examples: multi cavity Fabry-Perot interference filters; induced transmission filters having more than one metal layer; interference filter wedges for inexpensive monochromator applications; interference filters for the ultraviolet range; infrared interference filters for measuring the concentration of different gases like CH_4, CO_2, and CO; high optical damage threshold resonator mirrors consistig of TiO_2 and SiO_2 layers for 1055 and 1064 nm; resonator mirrors for LiF; F_2 colour center lasers (KrF, XeCl); circularly polarizing beam splitter cubes for compact disc players. A technology in the field of integrated optics was developed for producing optically bistable interference filters consisting of dielectric and semiconductor (CdS_xSe_{1-x}) layers and having light intensity dependent transmission spectra. We have been investigating the switching mechanism and its possible applications.

The group developing electro optical instruments has completed a laser ionization time-of-flight mass spectrometer, which works perfectly in industrial applications. New no-touch optical controlling instruments are under development.

The group of optical interferometry also works in the field of stabilization of lasers, mostly in frequency stability, which is a key factor in interferometry, the primary field of activity of the group.

Solid State Theory Research

In the field of solid state theory in 1987-1988 we have continued to study the charge- and spin density wave interactions with impurities. We developed the theory of pinning of spin-density waves by nonmagnetic impurities. The properties of two-level systems interacting with a degenerate electron gas have also been studied: we determined the partition function and investigated the scaling properties of a one-dimensional Coulomb gas. We examined the properties of different spin models; e.g. we have studied (1+1) dimensional spin models using a mean-field-like variational and renormalization group approach, and calculated the finite size corrections in the low energy states of the one-dimensional half-filled Hubbard model. In the field of heavy-fermion systems we have investigated the variational ground state properties of the periodic Anderson model by using the Gutzwiller method. The structural and electrical properties of quasicrystals have also been investigated. Furthermore, we have developed the theory of the slab waveguide with nonlinear boundaries.

In studying the physics of dynamical systems we examined the dynamical fractal properties and the relaxation processes in chaotic states of one-dimensional maps. The properties of fully developed chaotic one-dimensional maps were also studied in the presence of external noise. Furthermore, we investigated the multifractal properties in the one-dimensional random field Ising model. Phase transitions in probabilistic cellular automata were also studied.

Metals Research

The activities of the Metals Research Group in 1987-1988 focussed mainly on the study of amorphous metal hydrides, supported by a research grant. A rapid-quenching apparatus was set up which allowed us to prepare amorphous alloys in vacuum or in inert atmosphere. Arid amorphous Zr-Ni ribbons have been produced with this apparatus. An other apparatus was

built for introducing hydrogen from high-pressure (up to 40 atm.) H_2 gas phase into metals. We studied the hydrogen uptake by amorphous Zr-Ni alloys. In collaboration with other institutions both in Hungary and abroad, the following properties of amorphous Zr-Ni based alloys without and with hydrogen were investigated:

a) electronic structure from magnetic susceptibility (Univ. of Munich), high-resolution NMR (Inst. of Chem. Phys. and Biophysics, Tallin, USSR), UPS (Inst. of Microelectronics and Institute of Isotopes, Budapest) measurements and theoretical calculations;

b) diffusion of hydrogen through NMR studies (College of William and Mary, Williamsburg, USA);

c) phase separation upon hydriding (Solid State Dept. of Eötvös Univ. Budapest);

d) electrical noise (JATE, Szeged).

Partially Ordered Condensed Matter Research

The investigation of ferroelectric liquid crystals was continued in our laboratory. Liquid crystalline compounds exhibiting ferroelectric properties were synthesized, their impurity content was reduced by chromatography and checked by various methods. In cooperation with German, Polish and Russian colleagues binary and ternary mixtures were prepared in order to extend the chiral smectic C^x temperature range and to adjust pitch and polarization. The temperature dependence of the important physical parameters were measured and compared with the generalized Landau theory. The structure of ferroelectric liquid crystals is highly influenced by applied electric fields. Besides the electrooptical phenomena (reorientation of molecules, switching processes, instabilities) the electromechanical response (field induced vibration) of the substances was intensively studied. This effect was first observed in our laboratory. By means of laser light induced thermal gradient the order electricity of nematic liquid crystals was also investigated. The possible aliphatic packing and conformations in smectic A mixtures were studied by FTIR spectroscopy and some hints of the intercalation of the flexible end-chains were detected for the first time.

The amorphous semiconductor group deals mostly with basic research in the field of tetrahedrally coordinated and chalcogenide amorphous semiconductors. To shed some light onto the connections between the structure and the transport properties in amorphous silicon, structural investigations were carried out together with electrical and photo-electrical transport measurements. The localized electron states in the forbidden gap were investigated by DLTS and optical methods. These states depend on structure and

strongly determine the transport properties of the sample. We proved that, depending on the microstructure, the escape probability from the traps in the tail states can change by as much as an order of magnitude. An interesting effect was recognized in fresh, as prepared, gap-type samples: The conductivity increases three-four orders of magnitude at room temperature on a time scale of hours. Applying a short circuit between the two electrodes of the sample the original state can be restored. Metastable states were created in a-Si:H samples by different treatments, like annealing, irradiating by light, and applying electric field. The nature of these metastable states was determined, the kinetics of their creation, the location within the forbidden gap and their density were investigated by photoluminescence and DLTS methods.

Interesting photoluminscence transient effects were measured in Ge-Se glasses, which were connected to the creation of metastable localized states in the forbidden gap. Using the photodoping effect we have made optical grids of submicron resolution in chalcogenide thin films, demonstrating that this method might be very valuable in high resolution microlithography (VLSI).

Significant technical developments were achieved in rapidly quenched alloy production. A special laboratory melt-spinning facility was incorporated into a vacuum chamber. Mössbauer spectroscopy investigation of the short range order and electronic properties, and the calorimetric study of the thermal behaviour of Zr based alloys produced in this controlled environment is under way. A double electron gun ultra high vacuum vapour deposition machine producing Fe-B amorphous alloys is also being constructed and tested successfully. Preliminary experiments are also being made to deposit Fe-As, Fe-Y, Fe-Ca and Fe-Te films. Solidification, following the surface melting by nanosecond laser pulse, results in orders of magnitude higher cooling rates than that which is attainable in melt spinning. The experimental facility suitable for these studies was also successfully tested by investigating the Fe-B and Fe-Y systems.

During the reactor shut-down the neutron scattering activity was continued in cooperation with neutron sources abroad: Dubna, Saclay, Grenoble, Seibersdorf etc. The short-range order of amorphous alloys was studied by high momentum transfer experiments. The structure and dynamics of liquid crystals (smectics, glassy state), water solutions, biological objects as well as of high T_C superconductors was investigated by different neutron scattering techniques. Dynamic neutron and gamma radiography were utilized for industrial application.

SELECTED TOPICS

Joint Group For Laser Research of the Institute for General Physics (Moscow) and KFKI

I. Kertész

To accelerate the successful cooperation between the laser laboratories of the two Academic Institutes a Joint Group for Laser Research (JGLR) begun its activity in our Institute in mid-1987.

The aim of the JGLR is to develop further the portable mini-laser — based on numerous common patents — in two directions:

1. To make the mini LiNdLa-phosphate glass laser (MPQ) more versatile in all parameters: pulse energy, pulsewidth, wavelength, repetition rate and stability, using the original laser glass rod and LiF(F_2^-) saturable absorber (Q-switching) crystal or new laser materials as active and passive elements.

The MPQ-laser is working at the 1.055 μm wavelength while for several tasks a wavelength less dangerous for the eye would be desired. Other laser materials working in the eyesafe regions are not effective enough, their Q-switching to produce giant (MW peak power) pulses is expensive etc. Our idea was to combine the effective LiNdLa-glass with LiF(F_2^-) in a double role: passive Q-switch and active element of a color center laser, transforming the original wavelength into the 1.15-1.25 μm range.

Similar efforts gave about 30% conversion efficiency only, while the more effective perpendicular resonator geometries are large.

A coaxial geometry (Fig. 1) consisting of three mirrors forming two overlapping resonators was used. Mirrors 1 and 3 are ~100% for the 1.055 μm radiation forcing it to circulate in the basic resonator until it is converted by the LiF(F_2^-) crystal into the 1.15-1.25 μm range within the subresonator of mirrors 2 and 3, the latter being transparent (partly) for the converted wavelength. Our calculations showed that the ratio of the two resonator lengths and the concentration of the F_2^- color centers in the LiF crtystal is critical. For the optimal initial absorption — before saturation — the experiment gave ~40%. The output increased linearly with increasing output mirror transmission showing that the investigated 20-40% range is far from optimum but the 40% output coupling gave about 60% conversion efficiency (compared with the optimal 1.055 μm wavelength operation at the same pumping rate) promising a near to theoretical (~85%) efficiency for the optimal (T=50-70%) output.

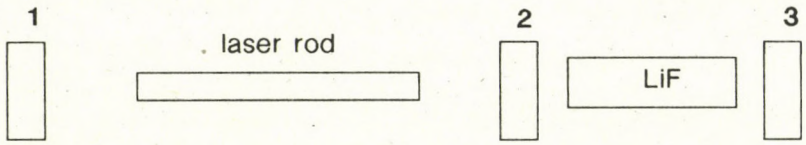

Fig. 1

Overlapping resonators of the LiNdLa-phosphate glass → LiF(F_2^-) laser

Mirror 1: ~100% for 1.055 and ~100% for 1.15 μm
Mirror 2: ~0% for 1.055 and ~100% for 1.15 μm
Mirror 3: ~100% for 1.055 and 20-40% for 1.15 μm

2. Our second aim was to develop a family of effective glass or crystal based midi-lasers delivering high enough powers for material processing and medical applications (and combine them with optical fibers and robots).

To overcome the limitations of the phosphate glass material in the repetitively pulsed regime, suitable for industrial and medical applications, slab-form active elements of better cooling properties were used. Laser elements of cylindrical and slab forms are damaged (fractured) in different ranges of pumping power. The ratio of pumping power limits for elements of the same length and cross sectional area for the two shapes is given by

$$\frac{P(fr,\ slab)}{P(fr,\ cyl.)} \approx \frac{3w}{2\pi t}$$

(where w is the width and t is the thickness of the slab). For high width to thickness ratio the pumping power can be increased significantly. With $3\times14\times125$ mm and $3\times10\times130$ mm slabs for 1.055 and 1.32 μm wavelengths at moderate repetition rate (2.6 Hz) 30 and 7.8 W were obtained. For 1.055 μm at medium (20 Hz) repetition rate 22 W was the output. Note that such reasonable 1.32 μm power could be achieved due to the slabgeometry-ensured high pumping only.

With a special cylindrical resonator the beam quality remains good in the whole frequency range.

Besides the phosphate glass we concentrate on non-exotic laser crystals of high performance to develop lasers of the same output power as the commercially available ones, but due to the higher efficiency in smaller, cheaper and more reliable form.

The first experiments with a ø 5.5×90 mm Nd, Cr:GGG crystal produced ~4% absolute efficiency which is about 1.5 times higher than that of the widely used Nd:YAG lasers.

The easier to grow Nd, Cr:GGG crystals of ø 6.8 × 125 mm offer possibility for multi-hundred watt lasers at 3-5 kW pumping and thus a new generation for the industrial laser market (low price, small dimensions, long lifetime).

Interaction Between the Conduction Electrons and the Two-level Systems of Metallic Glasses

K. Vladár

The concept of two-level systems (TLS) was introduced in the early seventies to interpret some anomalous features of the insulating glasses. The TLS is a consequence of the amorphous structure: there are always atoms or small groups of atoms which can be rearranged by quantum mechanical tunneling. Later these objects were found in metallic glasses too. Here they interact obviously with the conduction electrons but their calculated leading contributions to the electron transport properties differed from the measurements by orders of magnitude in certain cases. From the theory of magnetic impurities of metals or the X-ray absorption it is well known that the perturbation treatment applied on a Fermi-gas with dynamic scattering potential leads to infrared divergencies so the methods worked out here had to be adapted. The adaptation is non-trivial because of the complicated and mainly unknown form of electron-TLS interaction, only the strength of which can be estimated. Several renormalization methods were used which differ in accuracy in the different parts of the interaction. The results obtrained by Anderson's poor-man's scaling were extended to the next-to-the-leading logarithmic order by the help of multiplicative renormalization group technique. In another method the TLS-electron system was mapped on a one-dimensional Coulomb gas where it was possible to reach exact results in the dominant part of the bare interaction. It turned out that the electron TLS scattering of arbitrary shape goes to a Kondo scattering at low temperatures. This explained the very similar behaviour of the two kinds of scattering centers. The two states of the 1/2 spin impurity correspond in the analogy to the two states of the TLS while the spin states of the scattering electrons correspond to two orthogonal electron spherical waves. The two quasispins are strongly correlated below a given T_c crossover temperature. The renormalized values of the electron-TLS coupling solved the former contradiction between the theory and the measurements near T_c and gave the proper orders of magnitude for the electrical resistivity, TLS relaxation time and the inelastic electron lifetime.

Electron Scattering Mechanisms in Fe and Ni-based Amorphous Metals

B. Sas

The possibility of synthesizing metallic materials without long range order is the concern of a great many physicists.

The special characteristics of amorphous metals are as follows: the magnitude of the electrical resistivity is significantly greater than in crystalline state, resulting in a mean free path comparable to the interatomic distances; the temperature coefficient of resistivity (α) at room temperature is much smaller than in the crystalline case, and sometimes negative; the value of α is negative in all cases at low temperature $T < 10$ K (irrespective of its value at high temperature).

This low-temperature resistivity behaviour of amorphous metals can be interpreted by using different models. One is the Kondo model (based on the magnetic scattering); the other one, "the model of the two level systems" is of structural origin. Neither of the models provide a good quantitative fit to all experimental data.

The most promising framework for interpreting the resistivity behaviour at low temperature is the theory of quantum corrections: the so-called electron-electron (Coulomb) interaction and weak localization effects.

One difficulty in distinguishing between the various models is a surprising absence of suitable systematic surveys. Specifically no systematic study is known where the magnetic order may be progressively suppressed without significant changes in structure. These conditions are met in $Fe_{80}T_3B_{20}$ amorphous alloys where T = 3d, 4d, 5d transition metals.

The measurements of the temperature dependence of the resistivity of $Fe_{80}T_3B_{20}$ alloys have shown a universal temperature dependence at low temperature, which could be explained by the Coulomb interaction.

On the other hand, the high ($T > 10$ K) temperature behaviour is significantly modified by the magnetic behaviour of the transition metal impurities. The magnetic behaviour of the transition metals influences not only the temperature dependence of the resistivity at these temperatures but the temperature dependence of the thermoelectric power (TEP) and the anisotropic magnetoresistance (AMR) as well. It has been shown that the change of TEP and AMR could be explained (similarly to the crystalline alloys) by the change of the density of state ratio of d subbands at the Fermi level due to the influence of different transition metals.

The influence of transition metals on the transport properties of a paramagnetic amorphous alloys system $Ni_{80}T_3B_{20}$ was also investigated in order to make clear whether the influence of transition metals can be explained in

a similar manner as in crystalline dilute alloys. The experimental results have shown that this is not the case. The magnetic and transport properties of $Ni_{80}T_3B_{20}$ amorphous alloys are significantly influenced by the chemical heterogeneities and by the changes in the chemical heterogeneities due to the influence of the transition metal impurities.

The field dependence of the magnetoresistivity of the $Ni_{80}T_3B_{20}$ amorphous alloys could be quantitatively explained by the effect of the weak-localization with strong spin-orbit scattering and by the effect of the magnetic impurities.

The conclusion is that in both systems (the ferromagnetic Fe-T-B and the paramagnetic Ni-T-B systems) the dominant effects at low temperature are the weak-localization and the Coulomb interaction (characteristic of the strongly disordered systems). At high temperature the most important effect in the Fe-T-B amorphous alloys is the magnetic scattering due to the different transition metal impurities and in the Ni-T-B system the scattering due to chemical heterogeneities influenced by the same impurities.

Charge-density Wave Dynamics

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One of the possible symmetry breaking ground states of a metal, the charge-density wave (CDW) state, is readily found in various organic and inorganic systems with quasi one-dimensional structures. The CDW is a periodic spatial modulation of the electronic charge coupled to a periodic distortion of the underlying crystal lattice (Peierls distortion). The CDW couples to an external electric field resulting in collective transport phenomena, due to the collective response of the electrons condensed in the CDW. We have performed a wide variety of transport and magnetic resonance measurements to characterize the collective mode.

The most characteristic feature of the CDW response is nonlinear d.c. conductivity. Upon the formation of the CDW, a gap opens at the Fermi surface leading to a metal-insulator transition. With sufficiently high electric fields (in the order of 0.1 V/cm), however, the CDW can be set to move, which shows up as an excess current in addition to that carried by the single electron excitations across the band gap.

Perhaps the most direct evidence that the origin of the excess current is the sliding motion of the CDW comes from ^{87}Rb NMR measurements in $Rb_{0.3}MoO_3$. The incommensurate periodic lattice distortion accompanying the CDW causes a spatial modulation of the electric field gradient tensor at the

Rb sites which, in turn, results in the modulation of quadrupole shifts. As a consequence, the NMR line inhomogeneously broadens with a linewidth proportional to the CDW order parameter. When the CDW moves, the periodic lattice distortion oscillates, and a motional narrowing appears at high enough sliding velocities. The detailed agreement of the evolution of the NMR lineshape with expectations from transport measurements and theory provides unambiguous evidence for the existence of the sliding CDW state.

At low electric fields the interaction of the CDW with impurities and other lattice defects prohibits the motion of the condensate. The depinning of the CDW by electric field is very similar to critical phenomena at second order phase transitions: the CDW polarization diverges when the field approaches the depinning threshold from below, and the sliding velocity slows down following a universal power law when the field approaches the threshold from above.

The low field response is dominated by the interaction of the CDW with randomly positioned lattice defects, leading to a rich variety of metastable states, weak relaxation processes and hysteretic behaviour similar to those observed in structural and spin glasses and other disordered systems. In impure specimens the effects of disorder may suppress the critical behaviour.

In the sliding state the main mechanism of damping is the interaction with single electron excitations. As these excitations freeze out progressively with decreasing temperature, a qualitatively different CDW conduction takes over with extremely high differential conduction.

The investigation of this novel CDW mode is one of the main areas of the ongoing research.

Besides the low temperature properties at present we concentrate on the thermal and thermoelectric properties of CDW systems. Another perspective is the extension of research to the very similar SDW systems.

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RESEARCH INSTITUTE FOR MICROELECTRONICS (MKI)

In the period covered by this Yearbook the scope of activities of the Institute for Microelectronics ranged far beyond what its name implies. This is due, in part, to a substantial decrease of revenues from Microelectronics Enterprises, the only semiconductor factory in the country, following a catastrophic fire at their premises. The earlier more-or-less balanced development of technology research, technology and circuit design shifted towards the computer assisted design of gate arrays, and the development of an appropriate hardware and software package along with a new computer language.

Our accumulated knowledge enabled us to design and build a new facility for gate array production in the Videoton factory at Székesfehérvár.

Technological work was expanded in the direction of sensing devices. We were involved in the semiconductor technology part of pressure sensor production for MMG Works, Budapest. The preparation of special membranes required sophisticated technology.

Other sensors were also produced: microelectronics technologies were used to prepare miniature neurological electrodes and a position sensor based on magnetoresistance.

Studies of photolithography techniques have led to a better understanding of the chemistry of the photoresist during hardening.

Some hardware developments were also successful. Ion sources designed here are now getting onto the market, and complex automatic electronic testers were produced and sold abroad.

Our most important scientific achievements are covered in detail in the following chapters.

Research in Magnetism

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1. Introduction

Research in magnetism and investigation of magnetic properties of different materials play a fundamental role in modern science and technology. Our group has been working on problems involving magnetic oxides (magnetic insulators) and metallic glasses (metals without crystal structure) for many years. These materials have extreme properties, therefore they are good candidates for basic investigations. They are also very promising from the point of view of application, e.g. as high temperature superconductors and as soft magnetic materials with low loss at high frequencies.

2. Magnetic oxides

2.1 Ferrimagnetism of diamagnetically substituted charge-uncompensated Yttrium Iron Garnet

The low temperature anomalies observed in the temperature dependence of the magnetization of Ca^{2+}-doped yttrium iron garnet $Y_{3-x}Ca_xFe_5O_{12}$, (Ca:YIG), CaGa:YIG and CaSc:YIG cannot be interpreted in the frame of the existing theories of diluted and canted ferrimagnetism of the classical two-sublattice yttrium iron garnet. Substitution of charge-uncompensated Ca^{2+} ions into the non-magnetic yttrium sites leads to a low temperature decrease of the magnetization, photoinduced susceptibility, and optical and electrical effects. Extensive dilution with Ga^{3+} at the tetrahedral, or with Sc^{3+} at the octahedral iron sublattice of the Ca:YIG causes a 10 to 100% decrease of the saturation magnetization at low temperatures.

The temperature dependence of the magnetization of diluted, charge-uncompensated $\{YCa\}_3[FeSc]_2(FeGa)_3O_{12}$ garnets has been described by a three-sublattice model based on the temperature dependent localization of the extra hole introduced by the Ca^{2+} creating a new magnetic sublattice of tetrahedral Fe^{4+} ions: the dilution effects of non-magnetic ions in the Fe^{3+} sublattices; the canting of the undiluted sublattices, taking into account the lattice parameter dependence of the exchange constants; and the low temperature ordering of the paramagnetic Fe^{3+} ions having less than two magnetic neighbours in the exchange field of the ordered magnetic sublattices.

2.2 Hysteresis phenomena in $MBa_2Cu_3O_7$ high temperature superconductors

Magnetic hysteresis of granular high temperature oxide superconductors $MBa_2Cu_3O_7$, where M= Y, Er, Dy, Ho, Lu, Tm, Gd, was studied at 77K by vibrating sample magnetometer. The hysteresis curves depend primarily on the direction of the field sweep and slightly on the external field and sweep rate, as was born out by the findings of ESR investigations conducted at the Central Research Institute for Chemistry, Budapest. Spin-glass properties have also been demonstrated. Vortices formed by consecutive Josephson currents between superconducting grains are proposed to explain the hysteresis phenomena: the flux uptake of outer loops with an area 10^{-6} - 10^{-8} cm^2 is related to the fast ESR hysteresis, while that of the inner loops with an area around 10^{-9} cm^2 is related to the slow ESR hysteresis, the memory fading and the magnetization hysteresis.

2.3 Coercivity of epitaxial magnetic garnet films

Coercivity, H_c, is commonly considered as one of the most important parameters in applied magnetism. It is connected with the fundamental magnetic properties of a material, but it characterizes also its perfection via the distance dependence of the domain wall energy. However, different methods for measuring the coercivity of epitaxial garnet films yield different values of coercivity. On the basis of our measurements the domain wall coercivity field (measured by the low frequency oscillation method) can be considered as the real chatacteristic of domain wall and defect interaction. It is sensitive to the fine changes in the domain wall energy caused by wall structure changes. With this method one can determine the real wall motion coercivity of epitaxial garnet films, while other methods are rather macroscopic.

In agreement with the theoretical models it was shown that the domain wall coercivity field depends significantly on the properties of the domain walls, the most relevant characteristic parameter being the domain wall energy density per wall area. The wall coercivity measured on various types of domain walls in a single sample was found to be a linear function of domain wall energy density. The slope of this function, which represents the intrinsic coercivity of the sample, gives a good start for a quantitative evaluation of various theoretical models.

With the experimental decrease of the sample size a significant and surprising decrease of domain wall coercivity was observed in garnet films. It is suggested that the coercivity is related to the sample dimensions via the sample-size-dependent derivatives of the total free energy with respect to the domain wall positions. Even a very small change in the slope of potential

wells may cause an appreciable variation in the domain wall response to the applied field and therefore in the coercivity measured by the wall oscillation method.

2.4 High field domain dynamics in magnetic garnets

High field domain dynamic observations were made in magnetic garnet materials using double exposure laser flash method of 0.1 ns time and 0.4 m space resolution. The double exposure pictures of the domain wall revealed the appearance of moving dynamic micromagnetic structures (DMS) on the wave-like domain wall. By increasing the domain wall velocity the lateral motion of these structures became observable. Two types of these DMS's were observed moving in opposite directions. It is suggested that these movements are due to a different sign in the azimuthal angle of magnetization direction, so they are similar to two types of Bloch lines. The Bloch lines can be regarded as the result of the development of magnetization instability within the moving domain wall.

During pulse remagnetization of magnetic garnet films a periodic magnetic structure appears on the Faraday picture. Detailed analysis of the Landau-Lifshitz equation has also led to the formation of a periodic magnetic structure. The main wavelength λ_m and the formation time τ of these structures can be determined by the expressions

$$\tau = 2\pi \left\{ \frac{\alpha\gamma}{(1+\alpha^2)M} \left[(H - H_k)M - 2Ak^2 \right] \right\}^{-1},$$

$$\lambda_m = 2\pi \sqrt{\frac{2A}{(H - H_k)M}}.$$

The measured data provide a good fit to the calculated curve.

3.Irreversible magnetization in ferromagnetic materials

3.1 Model

In ferromagnetic materials irreversible magnetization processes are represented by rather complicated hysteresis curves. The mathematical description of such curves requires the use of multivalued, yet unambiguous, deterministic functions. The history-dependent series of consecutive Everett

integrals of the two-variable Preisach function can account for the main features of hysteresis curves in uniaxial materials. One of the main drawbacks of the traditional Preisach Everett model is the congruence of calculated minor hysteresis loops taken between the same external field limits but with different magnetic history and magnetization values. Experiments, however, contradict this intrinsic congruency property of the model.

We have introduced a modification to this traditional model on the basis of population dynamics considerations, removing the nonreal congruency property. The Preisach function is proposed to be a product of two factors of distinct physical significance: a magnetization-dependent function and a bilinear form of a single variable magnetic field dependent function. The magnetization dependent factor describes the population of the initial and final magnetic states of the individual magnetic units (domains, grains, particles, etc.) of the material, while the field dependent factor takes into account the probability of the switching of these units between the initial and final states. Thus the switching process of the magnetic units is separated from the bookkeeping procedure of their states during the build-up of the hysteresis curve. A practical numerical procedure was also given for the determination of the relevant functions and parameters of the model from measured hysteresis curves.

The proposed bilinear product model of magnetic hysteresis can be extended for application to other non-reversible physical processes, such as hysteresis curves related to first order phase transformations.

3.2 Experiments

Magnetic instability during magnetization reversal in crystalline materials was already systematically investigated by Néel (reptation and bascule effect). We found similar effects in the amorphous Fe-B alloy but the changes of magnetic polarization were smaller than in the crystallized state, and there was a bigger stability region inside the hysteresis loop. Induced anisotropy in this amorphous alloy lowered the reptation effect. This may be due to the redistribution of interaction fields.

4. Surface magnetic properties of metallic glass ribbons

Surface properties of metallic glass ribbons play a fundamental rôle in their bulk magnetic properties. Therefore in the last two years the investigation of surface magnetic properties had an emphasized role in our experiments on metallic glasses. The effect of mechanical stresses, heat treatments and processing conditions — especially rapid quenching in magnetic field and ion

implantation — on the surface magnetization curve (taken by magneto-optical hysteresisgraph) and domain structure (examined with the backscattered electron imaging method) was successfully investigated. It was shown that the surface coercive force, which is always higher than the bulk one, correlates with the quenched-in or applied stresses and may be decreased by heat treatment; but it needs a much longer heat treatment than one would expect from bulk magnetic measurements. The anisotropy introduced by rapid quenching in magnetic field can also be sensitively detected by the domain structure or by the surface magnetization curve. Ferromagnetic resonance (FMR) and Mössbauer methods were also used for surface investigations, mainly to follow the effects of ion implantation on metallic glasses.

Silicides and Implanted Thin Films

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Concentrated research efforts were directed in the last two years to the understanding of the solid phase reactions that govern the structure of thin films and near-surface layers of semiconductors. This activity was centered on semiconductor fabrication technologies in part available here and in part developed through international cooperation.

Different types of silicides were prepared in our institute. The earlier work on $GdSi_2$ was continued and epitaxial growth was achieved both on [100] and [111] silicon. The maximum thickness for epitaxial growth on [100] Si, i.e. the thickness above which the effect of lattice mismatch prevents epitaxial growth, was about 50 nm. In the case of Si [111] the epitaxial growth had a thickness limit above 300 nm. It was also shown that the phase formed during silicidation depends on the thickness of the metal.

Studies with X-ray Photoemission Spectroscopy (XPS) and Ultraviolet Photoemission Spectroscopy (UPS) revealed the electronic structure of rare-earth silicides ($GdSi_2$, $HoSi_2$). The p-d hybridization — the cohesive force of the transition metal-silicides — is changing in rare-earth silicides because of the lack of "d" states in the valence band of rare-earth metals and the valence band density of states is much more "p"-like than in transition metals. The hybridization should be between Si "p" states and either metallic "s" or rearranged "f" states.

The Si-$TiSi_2$ interface was investigated by means of UPS and X-ray diffraction. This interface is far thicker than the atomic scale. There is a 5-10 nm thick metallic layer which has not been identified yet in the Ti-Si phase diagram.

This interface layer probably exists in all non-epitaxially grown silicide films, which are extremely important for Schottky applications.

Implanted layers were studied both theoretically and experimentally to get a better insight into the as-implanted state. The Miedema parameter method was applied to silicon, and X-ray rocking curves were used to find out substitutionality. The process of regrowing at high temperatures was different in oxygen and in argon atmospheres, because in oxygen the not perfectly regrown surface layer was removed by oxidation and etching of Si.

Regrowth of implanted amorphous layers was studied by XPS and UPS in cooperation with Chalmers University, Göteborg. Conclusions led to proof of non-perfect regrowth at the very surface of the silicon.

The heavy ion implantation induces amorphous Ge with a valence band electronic structure markedly different from the well known tetrahedrally coordinated amorphous Ge. Structural data suggest that this amorphous Ge is in some respects liquid like.

Ion pulses of 200 keV, 50 ns duration and about 1 joule/cm^2 total energy were applied recently not only for producing doped layers and to form silicides, but also to organic substances to reduce the top layer's resistivity.

Test circuits were made for different types of Silicon-On-Insulator structures. Buried implanted layers were prepared by hot nitrogen implants at the KFKI, and laser annealed polysilicon layers were produced by two cooperating laboratories: Shanghai Institute of Metallurgy and Semiconductor Institute, Frankfurt/Oder.

Laser Assisted Technologies for Microelectronics

J. Farkas, A. Hámori, Z. Szabó

In the Microelectronics Research Institute a new research and development program has been started for the application of various laser beams and laser assisted processes in microelectronic technologies. This relatively new area provides challenging tasks in R and D activities.

Our new program includes the following main projects:

1. Laser based reticle pattern generator and stepper

A laser based reticle pattern generator and stepper system has been under development since 1987. Its first embodiment, which is expected to be in operation not later than by the end of 1990, has been planned to become an essential tool for small mask manufacturing stations. The system provides a way to solve the two main tasks of mask manufacturing:

- high speed reticle pattern generation, and
- precise step-and-repeat exposure.

The high speed pattern generation is done by using the raster scan pattern generation technique. A focused He-Cd laser beam scans the entire surface of the photoresist-coated mask plate. By means of an acousto-optical modulator the laser beam is switched on and off, according to the pattern under exposure. The scanning motion is carried out by both mechanical and acousto-optical means. The mechanical tool is the X-Y table of the EM 562 camera which is driven by a linear motor and is equipped with air bearings. The position signal is derived from Moire-type position transducers. The table is forced to perform scanning type motion at the highest possible constant speed. When scanning along the X axis, not only a single line but a whole strip is exposed. This effect is achieved by acousto-optical deflection providing a fast subscan and addressing 128 points along the Y axis. Thus the mechanical scan along the Y axis occurs in discrete steps corresponding to the width of the exposed strips. The result of this exposure strategy is an increase in speed and throughput by a factor of 20 as compared to the conventional reticle pattern generators.

To illustrate the complexity of the system here are some features of its main components:

- The printing head consists of a 40 mW He-Cd laser, beam splitting, steering and forming elements, an acousto-optical modulator and deflector. This part is equipped with intensity and beam position detectors driving independent feedback loops in order to stabilize the most important system parameters. A special electronic hardware is incorporated which temporarily stores the exposure information of a whole strip in a dual port RAM, and drives the modulator according to the beam and table position signals.
- The automatic focusing unit is equipped with an independent He-Ne laser light source and measures the distance between the mask surface and the focusing element of the exposing head continuously. It corrects any deviation from the optimal focal length due to imperfections of the mask surface or to out-of-plane motion.

— The mechanical scanning unit provides the required programmable motion and synchrony signals according to the actual table position.

— The computer hardware and software system is divided into two parts. The on-line part accepts the actual parameters of the pattern generator and commands the information transfer toward the printing head. The off-line part converts the data of usual CAD output format to a special bit map format capable of driving the pattern generator.

The most important parameters of the pattern generator are the following:

— maximum exposure area	100 x100	mm^2
— minimum structure size	10 x 10	μm
— focal spot diameter	4	μm
— position increment	4	μm
— throughput (100x100 mm^2, independent of pattern complexity)	90	min

The basis of the stepper system is an EM 562 type industrial step-and-repeat camera, made in the USSR. The camera has very good optical and mechanical properties, and with a proper up to date driving electronics it solves the task of reticle reduction and exposure with accurate positioning.

Some of its parameters:

— minimum line-width	1	μm
— accuracy	±0.2	μm
— mask size	6	inch

2. Mask repair station

In the mask production industry there is an ever increasing demand for a good mask repair station. Thus the development of one has been started for the removal of both opaque and transparent defects.

Opaque defects can be removed with the usual repair method: by the ablation of excessive chromium spots by means of laser impulses. Usually the area to be repaired has to match existing structures on the mask, therefore a shaped repairing beam is needed with adjustable dimensions. To avoid damage to the glass substrate we use laser impulses in the nanosecond time range.

The main element of the station is a Nd:phosphate laser made by KFKI. The Q-switch element is a LiF crystal.

The optical system is constructed by using commercially available microscope elements. There is an optical path for visual observation, which is essentially a normal microscope, and another one for the machining beam. The shaped machining beam with adjustable dimensions is produced by imaging slits of variable sizes. A He-Ne laser is used for aiming at the processing area.

Transparent defects are repaired by laser induced chemical vapor deposition. The masks to be repaired are placed into a special reaction chamber, in which metallic particles can be deposited by the dissolution of organometallic gases, e.g. $Cr(CO)_6$, $Mo(CO)_6$, $W(CO)_6$, etc. The processes are activated by temperature elevation induced by a continuous Ar ion laser. On the surface of a transparent mask plate the deposition process must start on an existing metallic spot and then an opaque line is written by the continuous movement of the laser beam. In order to obtain a continuous line the writing speed must be smaller than the lateral growth rate of the metallic film.

A computer-controlled experimental setup has been put into operation for the investigation of the processes involved and for the determination of the relevant technological parameters of the system.

Encouraged by the experiences, we started to build an experimental setup to write metallic and insulating films on silicon wafers and chips as well. The goal of this work is to realize a quick turnaround direct writing machine and a technology to finish gate arrays. The system will be based on an EM 552 type step-and-repeat camera made in the Soviet Union.

3. Research and development of laser activated technological processes

A general research and development program has been launched in cooperation with the Science-Research Center for Technological Lasers of the USSR Academy of Sciences, in the framework of the Komplex 2000 project.

In the R and D program the following laser activated technological processes are envisaged:

- chemical vapor deposition (LACVD)
- reactive ion etching (LARIE) — vacuum evaporation (LAVE)
- laser panthography including the development of a machine for direct writing on wafers by laser activated deposition, etching and ablation for microstructures.

Kr-F excimer lasers of 248 nm wavelength will be applied for laser activation. The lasers and the special optical elements will be provided by the Soviet partner and our task will be to develop the reaction chambers with the gas supply system, the motion tables and controllers, as well as the electronic hardware and software.

Our goal is the laboratory level investigation of excimer laser activated technological processes, and later, having aquired the necessary experience and knowledge, the production of useful technological systems for the microelectronics industry.

All the tasks mentioned in this section require the solution of common engineering problems as key elements for the design of the above listed technological systems. Such elements are, e.g.:

- high precision X Y table and motions
- positioning by interferometry
- autofocus systems
- special vacuum chambers
- high speed computer control and software, etc.

We believe that by solving these problems step by step, we will be able to construct a series of highly sophisticated equipment for use in technological research laboratories and in the microelectronics industry.

High Resolution Wide Field Holography

I. Bányász, G. Kiss, P. Varga

The challange facing photolithography as it is used in the microelectronic fabrication process is the need to integrate more and more functions, to achieve higher speed, to decrease the size of the individual elements and to increase the size of the total chip.The resolving power of the lens imaging the photomask onto the wafer has to be high (better than a micron) and the image field large (approximately one cm). Objectives meeting these requirements are derived from those developed for photography but instead of the original 5-7 lens components they contain up to 30 lenses with no effective chromatic compensation. Moreover the working distance between the front lens and the wafer is too small to allow space for in situ processing on the wafer's surface.

Holograms seem to be the best optical elements when high resolution and large object field area are required. The numerical aperture of the holographic recording system is limited by the maximum spatial frequency recorded by the hologram material. Good photographic materials offer

3-4000 lines/mm., i.e. for an on-axis object, a resolution of 0.5-0.6 micron can be expected. The advantages of holography in this area are well known, yet experiments in the early seventies resulted in only 2-3 micron resolutions and the research was discontinued. We have been carrying out experiments to find what the difficulties are in achieving the theoretical limit. For the purpose of comparison, through the experiments we calculated the transfer functions of real one and two-dimensional objects. In the latter case the object was a focal spot produced by a high N.A. microscope objective; in the first case it was a one micron wide slit. To obtain data for quantitative evaluation the intensity distribution was measured in the retrieved image directly by a photomultiplier and compared with the pre-experiment calculations.

The object to be registered was placed in front of the hologram in an off-axis position to simulate the extension of the real object. The plane reference wave was directed on the hologram from the same side as the object was located. The retrieval beam illuminated the hologram from the back, the auxiliary beams were directed at it from the opposite direction, thus the arrangement performed a delayed four wave mixing. Care was taken to work in the linear part of the characteristics of the holographic recording material.

Ideal transfer could be obtained when the circumstances valid for the theory were realized in the experiment, i.e. the auxiliary beams were exactly conjugate. This required careful directional adjustement of these beams. If the mismatch between the auxiliary beams was more than one milliradian, definite geometrical aberrations (astigmatism and coma) were observed [1]. The same effect was caused by the inaccurate replacement of the hologram after development. No third order aberrations took place with the auxiliary beams perpendicular to the hologram plane.

In order to attain a lesser degree of mismatch, the geometrical aberrations were covered by diffraction, but the effect of the mismatch persisted until such time as the auxiliary beams were adjusted to the maximum accuracy allowed by the size of the hologram. The ideal matching of the retrieval and reference beams is also influenced by the glass of the holographic plate. This thick plate is not plane-parallel. The unevenness of the surface covered by the recording layer cannot in itself influence the accuracy, because these effects are automatically eliminated in the four wave mixing process. The auxiliary beams are not exactly conjugated on the recording surface because the reconstructing beam gets distorted by the uneven back glass surface. To eliminate the influence of this surface a good quality plane-parallel glass plate was applied to the back side with an index matching fluid. It was only then that the calculations and the measurement produced identical results.

Any deviation from the ideal transfer causes serious defects when recording more complicated patterns. The spread of the light intensity that occurs in the case of a non-ideal transfer causes the rapid fall of the Strehl ratio in the reconstructed pattern [1] and the photoresist gets unequally exposed

on various parts of the chip. Moreover, non ideal transfer is manifest in the appearance of higher intensity side lobes of the diffraction pattern. The spurious interference between side lobes leads to the occurrence of ghost patterns too.

If mismatch and the distortion of auxiliary beams are eliminated, holography can really be advantageous when resolution of one micron or better is required.

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Adaptive Control of Czochralski Growth

G. Szabó, Z. Juhász

1. Introduction

The Czochralski growth method is widely used for producing high quality single crystals of semiconductors and different oxides. Several different techniques have been developed to achieve automatic diameter control of the Czochralski process. Most of the traditional control systems are based on a PID controller where the weight of the crystal (or crucible) serves as an input signal for the controller. The first versions of these controllers used analog electronics, while the later versions are computerized. The direct computerization of the PID controller, however, has all the drawbacks of this control including the lack of parameter estimation and tuning. Advanced processing, however, requires a more sophisticated control system providing homogeneous dopant distribution and low defect concentration. These requirements may be fulfilled by developing an adaptive controller utilizing the possibilities offered by computerization.

Earlier, our activity was mainly concentrated on the investigation of temperature oscillations caused by the Rayleigh-Benard instability in the melt. Due to this temperature oscillation the growth rate is not constant, which results in an inhomogeneous dopant distribution in the crystal. The harmful effect of this phenomenon may be reduced by decreasing the temperature gradients in the melt and by applying an external magnetic field. In order to reduce the concentration of dislocations in the grown crystal, low values of

temperature gradients are also required. These modifications, however, make growth control very complicated because the dynamical behaviour of the growth process may easily lead to instabilities or non-linearities under these conditions. This is the reason for the widespread research in the dynamical behaviour of the growth process.

At the beginning of our project, we studied the growth process by measuring simultaneously the crucible weight and the melt temperature during the growth of $Bi_4Ge_3O_{12}$ crystals. The resulting temperature and weight signals were considered the input and output of a linear system, and the dynamic behaviour was characterized by a transfer function. This work was extended to determine the transfer function relating the growth rate to the heating power variation. In principle, the knowledge of this transfer function allows us to determine the optimum control parameters. In agreement with our expectations, we have observed significant differences between the transfer functions measured at different stages of crystal growth. The continuous variation of the transfer function is a consequence of the slow change in the thermal and geometrical conditions during crystal growth. The significant changes emphasized the necessity of a self-tuning control system. This inspired us to develop an adaptive control system for Czochralski growth.

2. Adaptive control

The concept of the adaptive control is well known in different areas of physics, chemistry and industry. This control is applicable where the tuning of the parameters is crucial and their values change slowly enough. The recent progress in the field of personal computers allows us to use this kind of control for a relatively simple system such as a Czochralski apparatus.

The adaptive control system determines the transfer function of the system to be controlled by measuring the input and output signals simultaneously. On a discrete time scale the transfer function is described by an AutoRegressive-Moving Average (ARMA) model. The ARMA model introduces two sets of coefficients "a" and "b" determined by a suitable fit from the measured input and output data. Having a sufficiently large number of data, one can reduce the undesired effect of the noise disturbing the control as well as the measurement of the input and output signals.

Knowing the transfer function one can plan the future series of input data resulting in the desired system response. On the other hand, a comparison of the last series of measured weight data and the model response yields an estimation of expected disturbances in the weight signal. Using the so-called multistep predictor method, the trend of perturbations can be predicted and taken into consideration when planning the future input signals. In the control

process the effect of unpredictable future noises can be reduced by repeating both the parameter estimation and the multistep prediction in each period. With a suitable choice of the number of parameters, the numerical computation required may be carried out twice a minute using an IBM AT personal computer. Since the characteristic response (or delay) time of the Czochralski growth is generally longer than a minute, the real-time modelling of growth and the adaptive control may be performed by this commercial PC. In our present adaptive control algorithm the parameters of the ARMA model are determined without knowing any physical quantity of the growth process; thus, it can be easily adapted to any material.

3. Control of Czochralski growth

In the Czochralski growth method the growing crystal is pulled out from the melt contained in a heated crucible. The diameter of the rotating crystal is determined by the time variation of the heating power. At a constant pull rate the actual diameter may be evaluated from the decrease of crucible (or increase of crystal) weight, taking the meniscus effect into consideration. An electronic balance having a sensitivity of 0.01 g is used to weigh the crucible with a sampling time of 30 s.

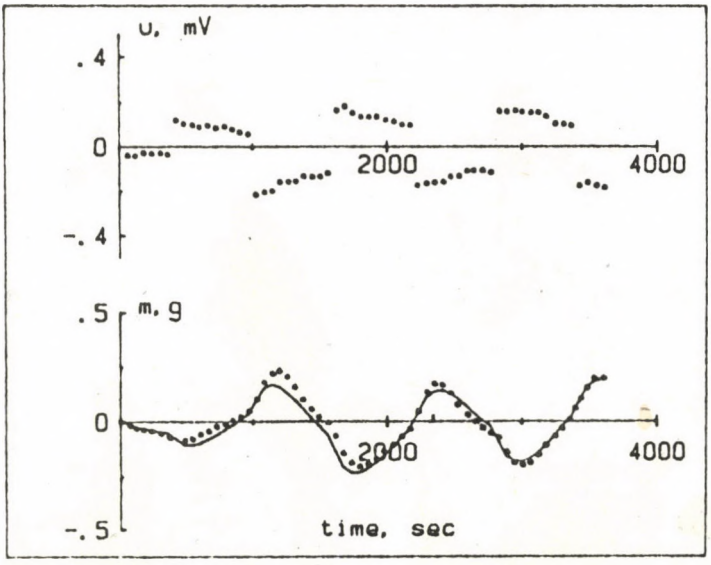

Fig. 1

Typical input (U) and output (m) sequences measured during necking. Points are measured data and the full line is the model response to the input sequence.

Any change in the heating power results in a time-dependent variation of the crystal diameter (or weight). This transient process is characterized by a transfer function relating the crystal weight to the heating power measured in units of the control voltage. Figure 1 shows a sequence of the measured input and output signals and the full line represents the response of the adjusted model following the input sequence.

Figure 2 demonstrates the significant differences in the transfer functions measured at the necking range of the growth of a $Bi_4Ge_3O_{12}$ single crystal. As expected, the magnitude of the response increases with the crystal diameter. At the same time the dynamic response of the system gradually slows down. This slowing down is characteristic of the dynamic behaviour of the system during the whole crystal growth process, including the cylindrical range. A significant change in the short-time behaviour was observed at the beginning of the cylindrical range. It has also been found that the form of the transfer function is very sensitive to the value of the pull rate. These observations convinced us of the need to develop a continuously tunable control system.

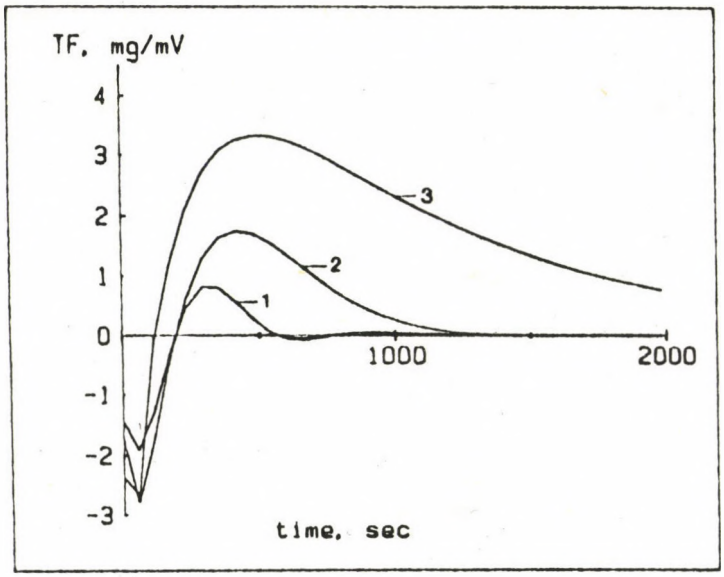

Fig. 2

Typical transfer functions relating crucible weight to heating power. The curves were measured in the necking range at crystal diameters of 5 mm (1), 11 mm (2) and 18 mm (3) for 1.5 mm/h pull rate.

Recognizing that the dynamic behaviour of the growth process changes gradually during growth, we have decided to develop an adaptive control system. The present version of the adaptive control system is based on an IBM-AT personal computer connected with A/D and D/A converters. The input and output signals are measured with a sampling time of 30 s, and the coefficients of the ARMA model are estimated in each period from the last 100 data. The expected perturbation is estimated by the multistep predictor method mentioned above. Using an optimization technique based on the steepest descent method, the control policy is designed to reduce the power and growth rate fluctuation. During growth, the weight and power signals, as well as the last transfer function, are monitored on the display and stored on a hard disk.

A subsequent analysis of the time variation of the transfer function can inform the crystal grower how to modify the geometrical arrangement and thermal conditions in the chamber. For this, however, we need a better knowledge of the effect of boundary conditions on the characteristics of the transfer function. This research is in progress.

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INSTITUTE FOR ATOMIC ENERGY RESEARCH (AEKI)

Calculational Model of the VVER-1000 Reactor

After a long preparatory period the development of the calculational model of the VVER-1000 type power reactor started in 1987. The government's decision on the extension of the Paks Nuclear Power Plant (Paks NPP) using this type of power reactors gave an impulse to the activity.

The calculation of the VVER 1000 type power reactors requires coupled neutron physics and thermal hydraulic modelling. The calculational model is constructed in a hierarchical way, the three levels of hierarchy (the so-called geometrical levels) being the elementary cell, fuel assemblies and the reactor core. From the neutron physical viewpoint more sophisticated modelling is necessary at the simpler geometrical levels, providing the calculations at the more complicated levels with quantities characterizing the neutron physical properties of the geometrical elements. Consequently, the choice of appropriate boundary conditions at the simpler geometrical levels requires essential assumptions. This problem is solved in our model by using response matrices. From the thermal hydraulic viewpoint the calculational modelling begins at the reactor core level and proceeds in the opposite direction, however, the connection of the different levels of calculation requires special methods like in the neutron physics procedure. The two kinds of calculations are coupled through the heat source evaluated in the neutron physics calculations and the actual temperature, void, etc. distributions determining the parameters of the response matrices.

The modelling extends to steady state, quasi-static and transient cases. Thus nominal operational conditions, burnup, xenon- and samarium transients and even certain accident conditions can be treated. The extreme fast transients of loss of coolant accidents (LOCA) are excluded.

The program system KARATE, which collects all the calculational models described above, is under development on the BASF computer of KFKI. KARATE is realized as a modular program system.

The functional specifications of KARATE were elaborated in 1987. The realization of the system started in 1988. The system should be ready by the end of 1990. It will then be suitable for performance and cycle design calculations. Moreover, KARATE will be probably used for safety analysis purposes and as a background of reactor core monitoring.

Experiments on the ZR-6 Critical Facility

Measurements on the ZR-6 critical assembly started in 1973 and are due to be continued up to the end of 1990. In 1987-88 the following measurements were carried out:

1. The investigation of water-steel mixture as a radial reflector

The investigations started in 1986 were continued. In this second period not only the spatial distribution of energy release, but the neutron spectrum at the core - reflector boundary was examined as well.

2. Noise diagnostic measurements

The effect of injection of air bubbles and vibration of absorber on the neutron noise spectra were investigated. Dependence of the phase between the signals of the axially placed neutron detectors on the axial height of the air injection was found. The trajectory of control rod period doubling and other non-linear effects were measured.

3. Investigation of rectangular cores, containing steel plates

The investigated configurations served as imitations of lattices, similar to ones in spent fuel storage basins. The plate material (borated and stainless steel), the gap size between the plates and the contents of the gap (water or fuel) were varied in the experiments. Criticality parameters and energy release distributions were measured.

4. Investigation of small fuel sub-assemblies

Configurations containing small (61 rod) fuel sub assemblies were investigated. The energy release distributions were measured in all the fuel rods, in order to get precise mean values for the sub assemblies, to validate coarse mesh calculations.

5. Measurements on cores containing gadolinium based absorbers

Absorber rods containing gadolinium were examined in different configurations. The gadolinium content of the rods was varied. Criticality parameters and energy release distributions were measured. The investigations will be continued in 1989, the neutron spectrum near the absorber rods will be examined as well.

Power Plant Core Monitoring

The VERONA plus core monitoring system was fully installed by the third quarter of 1987 at units three and four of the Paks NPP.

The main goal of the system is to monitor continuously the detailed power distribution within the active core. This is the only way of finding the critical regions in the core, where the distances from the safety limits are the smallest. There is a great economic pressure to minimize these, so called, safety margins. It is evident therefore that the accuracy of the reconstruction of the power distribution is of primary importance. The reconstruction of the power distribution, i.e. the combination of the information gained from the measurements and the theoretically expected distributions, is not unequivocally defined, therefore the VERONA plus system incorporates several options. The basic problem is that the measured distribution only partially covers the area of interest, while the derivation of the theoretical distribution involves several approximations.

The efficiency and accuracy of the several options could only be studied by comparing them using real measured sets of data collected at different characteristic operational modes of the reactors. On the basis of a rather voluminous data library (about 20 Mbytes) a detailed study has been performed. The study has shown that by applying the most efficient options, accuracy close to 3 percent can be achieved in the power distribution reconstruction. Based on these results official authorization of the system at both units has been achieved.

Industrial Noise Diagnostics

The construction work on the reactor noise diagnostic measuring system of Units 3 and 4 of the Paks NPP has been completed. This part of the total system is able to handle in core and ex core neutron noises as well as temperature and pressure fluctuations. A duplicate of the noise diagnostic system operating at the Power Plant is used for research purposes in the KFKI AEKI.

The analysis of the measured noise signals has been continued. As a result of such analysis the effects in the pressure spectra have been identified and also vibration of a control element has been noticed. Effects of subcooled boiling were analyzed and related to the energy production per unit length. We developed a new method for the identification and validation of sensors.

The planning and elaboration of a completely new system of nuclear power plant noise signal handling and evaluation has been initiated. The result of this development will be a noise diagnostic expert system based on knowledge and artificial intelligence.

Noises from partial discharges in high voltage transformers have been detected and analyzed in sonic, ultrasonic and very high frequency ranges. The new method can be used to diagnose events that signal potential breakdowns in the equipment.

Thermohydraulics

Considerable effort was concentrated on experimental investigations of different transient processes on the integral-type thermohydraulic mock up facility called PMK-NVH. The tests performed included the following areas:

- 7.4% cold-leg break cases with different assumptions on emergency core cooling system (ECCS) availability;
- natural circulation both in single and in two-phase conditions;
- loss of different numbers of main circulating pumps;
- loss of feedwater followed by stuck open pressurizer PORV (pressure operated relief valve);
- partial rupture of the steam generator primary header with a consequent loss of primary coolant via the secondary side;
- 7.4% cold-leg break with the modelled connection line draining water from the hot leg loop seal to the cold leg.

The last two tests directly supported the assessment of backfitting proposals for the Paks NPP. These cases were also covered by several parametric calculations for the plant itself using the RELAP4/mod6 computer code. As to the last item, both experimental and analytical investigations support the view that installation of the connection line between hot and cold legs does not change core conditions in a significant manner during a small break accident.

Following the first Standard Problem Exercise (SPE 1) in 1986 the IAEA offered a second one to its member states. The SPE 2 was also based on a small-break test performed at the PMK-NVH test facility: a 7.4% cold leg break with 3 of the 4 hydroaccumulators available. Participation was even higher than in SPE-1: calculations were submitted by 18 institutions from 14 countries.

The safety analysis of the VVER 1000 blocks requires the investigation of LOCAs of different types. An important regime of the thermohydraulic transients in course of LOCA is the reflooding of the reactor core. The computer codes applied for the above analysis need several empirical formulas for the solution of basic equations.

An experimental loop is constructed for the elaboration of necessary experimental information on the rewetting phenomenon. The facility allows not only steady state measurements but also the effect of oscillations due to unbroken loops can be simulated. It is also possible to investigate the top, bottom and combined injection of the emergency core cooling (ECC) water into the system.

The first experimental results will be published in 1989.

An important field of the activity in the Thermohydraulics Department is the development of the thermohydraulics part of the KARATE program system described in detail earlier.

Health Physics

Ultrathin $CaSO_4$:Dy and LiF-7 thermoluminescent dosemeters, embedded in teflon were used in space dosimetry.

An International Intercomparison was carried out for environmental thermoluminescent (TL) dosemeters organized by the Environmental Monitoring Laboratory, New York, USA.

Sensitive $CaSO_4$:Dy bulb dosemeters are used for environmental monitoring along with the portable TLD reader PILLE (developed earlier for the measurement of the exposure of cosmonauts during space flight) in the territory of KFKI and in the vicinity of the Paks NPP.

An automatic image analyzer was developed for evaluating solid state nuclear track detectors. The system was used for detecting hot particles collected in the environment after the Chernobyl accident, also for investigating the neutron emission of spent fuel elements of nuclear power stations.

Regular measurements of ^{131}I, ^{134}Cs and ^{137}Cs content in humans after the Chernobyl accident have been carried out by whole body counting on selected groups of children and adults. The effective committed dose equivalent of the Hungarian population due to the incorporated ^{131}I, ^{134}Cs and ^{137}Cs radionuclides were investigated comparing the results obtained by direct measurements and model calculations.

In cooperation with a hospital, a method for the determination of the mass of human thyroids in different age groups has been developed by means of ultrasound technique.

The long term distribution and retention pattern of ingested ^{57}Co were investigated in a volunteer.

The phoswich low energy photon detector of the whole body counter was calibrated for ^{239}Pu and ^{241}Am deposited in different organs of the human chest in the frame of a co-ordinated research programme organized by the International Atomic Energy Agency.

A significant part was taken in the designing and development of (i) the whole body counter of Paks NPP, (ii) whole body counters for small animals, (iii) a mobile environmental laboratory and whole body counter.

Theoretical models were developed to determine the deposition efficiency of aerosols in a single bifurcation of the human tracheobronchial tree. In the analysis the fundamental physical processes were treated as simultaneous mechanisms. The model allows us to calculate the integral and the differential distribution of deposition along the airways of both spherical and fibrous particulate matter, i.e. a spatial distribution of use in microdosimetry computations. This model was then applied to predict aerosol deposition in the symmetrical Weibel's Model A and to study the effect of airway variability and asymmetry on particle deposition in the human lung.

Further development of the human and rat stochastic lung models was accomplished where the random walk, deposition and exhalation of particles were computed.

Calculations were made for the determination of the detector response in the hermetic space of the Paks NPP by the changing of the earlier developed adjunct Monte Carlo calculating method.

In situ measurements were continued in 1987 in the vicinity of KFKI and several points of Budapest in order to determine the variation of environmental radioactivity after the Chernobyl accident.The distribution of ^{137}Cs and ^{134}Cs isotopes were investigated in the soil. The knowledge of the dis-

tribution is essential for dose assessment. In situ measurements were also carried out in the environment of the Paks NPP in order to detect radioactive noble gas in the case of elevated levels of emission.

The regular monitoring of the environmental radioactivity was continued both by in situ and sample gamma spectrometry. The air activity concentration and the deposition of radionuclides were regularly measured in order to investigate the resuspension of fallout radioactivity. Comparative measurements were made in cooperation with experts from different Austrian and Czechoslovak research institutions, aiming mainly at the investigation of the distribution of radionuclides on the surface and in the upper layer of the soil.

Alpha spectrometry of transuranium elements (^{239}Pu, ^{241}Am, etc.) were carried out in fallout and soil samples.

Hot particles were collected in Budapest air after the Chernobyl accident. Their gamma and alpha spectrometric analysis was carried out and the health risk of hot particles was estimated.

A computer program system was developed to calculate the free in air kermas and effective dose equivalents that originate from nuclear power plants at normal and accidental conditions. So an IBM-compatible personal computer evaluates on-line the meteorological and emission data produced by the telemetric environmental monitoring system of Paks NPP. The newest version (1988) of the computer program — adapted to the starting of the 1000 MW block — is also applicable for several emission points.

Chemistry

By continuing the research on the electrochemical behaviour of fractal metal surfaces we studied the kinetics of the diffusion controlled electrode reactions and the impedance of fractal blocking electrodes. The results are as follows:

1. The frequency dependence of the admittance of a self similar blocking fractal electrode is of CPE (constant phase element) form i.e.

$$Y(\omega) = \text{const} \cdot (i\omega)^{\alpha}, \text{ and}$$

$$\alpha = (D_b - 1)/(D_w - 1)$$

where D_w is the fractal dimension of the working electrode and D_b is that of the current density distribution at the bottleneck region. This is a generalized form of our equation

$$\alpha = 1/(D_w - 1).$$

2. The diffusional (Cottrell) current to a fractal electrode also exhibits power-law time dependence and the exponent is given by

$$\alpha = (D_W - 1)/2.$$

This has three consequences:

a) The generalized Warburg impedance has the CPE form with the above exponent;
b) The Riemann-Liouville Transform of order α brings arbitrary waveform voltammograms to perturbation invariant forms;
c) The fractal ($D_W < 2$) rotating disc electrode exhibits power-law rotation frequency dependence with the same exponent α.

By making use of the spin trap technique and ESR measurements direct proof was rendered for the production of atomic hydrogen at illuminated tungsten bronze/aqueous solution interfaces.

An outline of a new approach to electron-ion recombination and electron localization in dipolar media has been suggested treating the pair of charge carriers as to be in a Rydberg state. Some macroscopic mechanical interpretation has been developed for the transversal and longitudinal dielectric relaxation times.

Substituent effects on high energy halogen replacement by recoil halogens obtained via different nuclear processes have been studied in equimolar mixtures of mono- and disubstituted benzene derivatives. Correlation of the results using the Hammett relationship has shown a measurable dependence of the yields on the second substituent for chlorine replacement by recoil ^{38}Cl, ^{125}I and ^{211}At whereas practically none for the replacement of chlorine by recoil ^{18}F and of fluorine by recoil ^{38}Cl. This phenomenon has been interpreted in terms of two different reaction mechanisms playing a role in these energetic proceses.

Investigations on the kinetics and pH-dependence of the electrophilic astatine addition to ethylene have been continued in cooperation with the JINR, Dubna (USSR). The results show that in neutral media HOAt whereas in acidic solutions the more reactive protonated hypoastatous acid is responsible for the formation of ethylene astatohydrin.

In the field of isotope effects the vapour pressure difference between CH_2Cl_2 and CD_2Cl_2 was measured betwen -50 and 40 °C. The experimental data were interpreted within the framework of the statistical mechanical theory of condensed phase isotope effects. Experimental data on the vapour pressure isotope effects of deuterated haloforms were analyzed in order to obtain information about the change of anharmonic force constants on condensation. The vapour pressure of heavy water at its triple point — which is an important reference point — was determined with high accuracy by dif-

ferential capacitance manometry. In cooperation with the Research Insitute for Solid State Physics of KFKI and the Laboratoire Leon Brillouin CEN Saclay (France) the structure of aqueous tetramethyl urea solutions were studied by different neutron scattering techniques.

Based on earlier results, the diffusion coefficient of orthopositronium has been determined as a function of temperature in normal and heavy water, and the results were found to be significantly different.

The positron Doppler broadening technique was applied to neutron irradiated reactor steels. A correlation was found among values of the line shape parameter, Vickers hardness and the absorbed neutron dose. The measurements were made in collaboration with the Paks Nuclear Power Plant.

Apparent molar volumes of different sodium alkylsulphates have been determined in normal and heavy water. The difference between normal and heavy water data was found to depend on the alkyl chain length. The apparent density in the core of sodium alkylsulphate micelles was found to be different from the density of corresponding alkanes, indicating different packing in the two media. The measurements were made in collaboration with the Technical University of Heavy Industry, Miskolc.

Ferrocene analogues of chalcone substituted in the ortho position were prepared and investigated by ^{13}C NMR and cyclic voltammetry. The change in the oxidation potential of the ferrocenyl group and the changes of the electron densities at the carbon atoms in the molecules caused by the substituents were correlated.

In the field of laser ionization mass spectrometry, experimental and theoretical researches are being pursued. On a linear time-of-flight mass spectrometer the kinetic energy distribution of laser generated positive ions was studied. Another instrument supplied with energy focusing ion reflector is under development, which utilizes optimized ion lenses designed by the group.

Theoretical investigations of laser ionization processes are going on in the frame of a cooperation with the University of Antwerp (Belgium). A hydrodynamic model was adapted to the detailed description of laser–target interaction. A simplified model has also been developed to interpret the threshold behaviour of laser ionization phenomena.

A new project was started in 1987 dealing with the chemical aspects of nuclear fuel behaviour. The investigation of corrosion processes and effect of chemical changes during reactor operation on the heat conductivity of the gap in the fuel element are in the centre of interest.

An AEI MS-702R spark source mass spectrometer with photoplate detector is used for trace element analysis. The photoplates are evaluated by a Carl Zeiss Jena type G2 microdensitometer modified in our laboratory for fully automatic work.

Successful experiments were accomplished to determine subnanogram amounts of trace elements in less than 1 μl liquid sample. It involves the developing of a new experimental method ("tip top technique") and a new data evaluation process. The precision and accuracy of the results are not worse than the conventional SSMS ones.

New application fields have been opened by the laser plasma ionization method: e.g. trace analysis of ceramics and analyses for the semiconductor industry, including analysis of primary material and end product.

A computer controlled target-mover was developed and built for laser measurements. It allows the automatic scanning of the desired part of the measured sample in conformity with laser pulses. This system expands continuously and enables the mass spectrometer to be fully automatized and archive the parameters of measurements.

In the field of radioanalytical chemistry the research on separation methods has been continued. To achieve fast procedure kinetics of solid/solution heterogeneous exchange reactions, first of all the effect of the structure of solid phase on the kinetics was investigated.

The neutron activation analytical method was applied for the determination of trace elements of biological interest in different biosamples. Determination of the bromine level in human brain suffering from brain tumor was carried out to obtain information about the effect of a cytostatic agent dibromodulcitol. Detailed investigations were carried out to study the distribution of trace and minor elements of paprika plants.

Within the scope of an international research program coordinated by the IAEA, nuclear and nuclear-related analytical techniques have been developed to study environmental pollution associated with solid wastes. Thus, among them Instrumental Neutron Activation Analysis (INAA) has been used to analyze coal fly ash particulates polluted into the environment. Samples were collected from different fractions of coal fly ash and the sampling has been performed by filtration using Nuclepore membrane filters.

The analytical methods are quality controlled by means of co analyzing reference standards; the natural radioactivity of the species have been also investigated.

Recontamination of high purity solid state surfaces can easily be caused in high tech using chemicals and solvents for rinsing, having not the desired purity quality as specified by the bulk cleanness of the solid state crystal. Therefore activities have to be performed both for purification and analytical characterization of the solvents.

This is considered as the scope of the research programme carried out in cooperation with the Central Research Institute for Chemistry and with JINR (Dubna). Isotope tracing has been used for any significant impurity element

to study the behaviour and retention of contaminants in various sample preparation processes. Reproducible results could be obtained by vacuum evaporation in the presence of MS-grade graphite absorbent.

Neutron irradiations and measurements are performed in the JINR laboratory using the IBR-2 pulse-operated nuclear reactor. Within this program 20-25 elements are studied and checked.

In the field of neutron generator activation analysis a measuring technique was adapted for counting X-rays after 14 MeV neutron irradiation. A sample preparation method was elaborated for the analytical studies. The empirical coefficient method was used together with the internal standard method for the determination of silver, antimony, cadmium and bromine by 14 MeV neutron induced X-ray measurement.

The X-ray fluorescence laboratory was occupied with environmental monitoring problems like contaminated soils, coal fly ash and aerosol. In cooperation with the Syberian division of the Soviet Academy of Sciences a high sensitivity analytical method is being developed to analyze low concentrations or small volumes.

The possibilities of continuous SO_2 monitoring in gas phase applied to volume percent ranges have been examined by X-ray fluorescence technique. Mathematical simulations and model experiments have been performed.

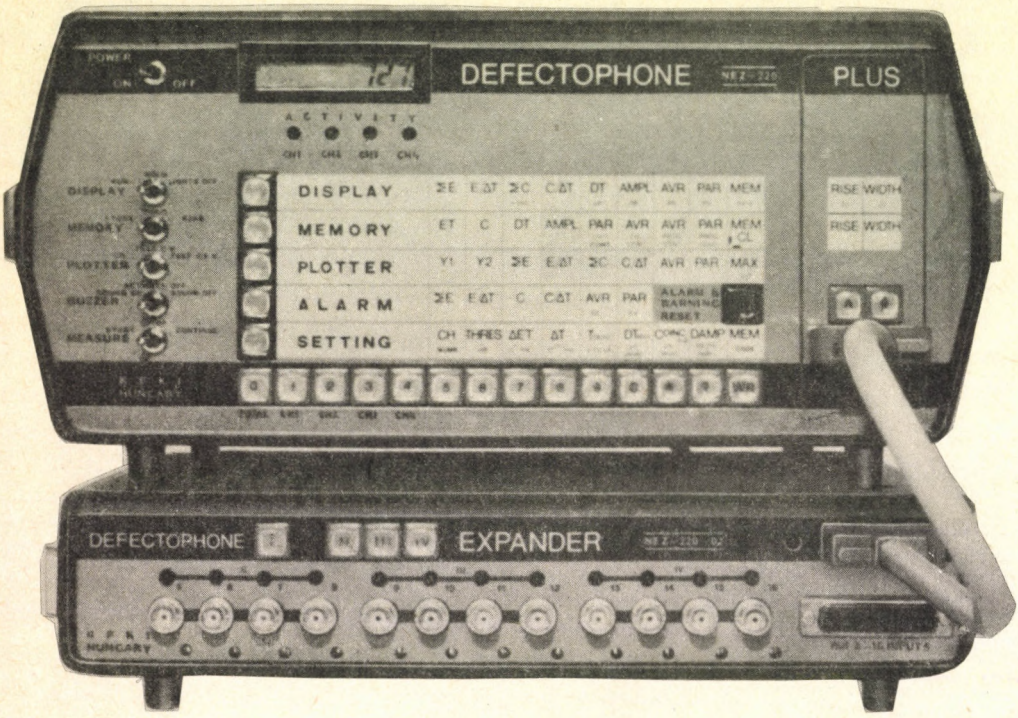
In the field of life time calculation of PWRs, we participated in the development of the In-service Inspection Testing and evaluation of its results at NPP Paks. To develop the fracture testing technology of irradiated and surveillance specimens we used the dynamic testing of round notched tensile bars.

Acoustic Emission Techniques

The importance of non-destructive testing in investigating industrial materials and structures is growing. Among its methods one of the newest and most promising inspection procedure is based on monitoring acoustic emission, i.e. the ultrasound activity of the inspected material. Its methodical problems, instrumentation techniques and applications were studied in the Institute during the last decade. In 1987-88, both instrument development and applied research were carried on.

One obstacle to spreading non-destructive testing by acoustic emission in Hungary was the lack of special measuring instruments. To solve this problem, the first model of a versatile, portable, multichannel acoustic emission analyzer named Defectophone was developed in 1984. This model was improved and completed during 1988 by developing optional units (plug in unit Plus, 12-channel Expander, etc.). Now, this family of acoustic emission instru-

ments — System Defectophone Plus — offers a complete set of hardware and software for the analysis of acoustic emission signals. Software has been elaborated for IBM-PC/XT/ATs both for remote control and for data acquisition. Defectophones are manufactured in the Institute, not only for laboratories in the country, but also for users abroad.



A 16-channel acoustic emission analyser: Defectophone Plus Expander

A multichannel leakage detection system — based on acoustic emission sensors — has been developed and put into operation at Paks NPP. The system is computer-based and operates with special software for acoustic diagnosis.

Applied research has been focussed in our laboratory on the question how acoustic emission inspection techniques can help solve real industrial non-destructive testing problems. A typical, major problem is the inspection of integrity of pressure vessels, during both hydrostatic pressure tests and normal operation. Acoustic emission signals can deliver early warning on formation or propagation of cracks. Among our applications, the largest object was the reactor vessel of the Paks NPP where a hydrostatic pressure test was monitored.

PAPERS, CONFERENCE CONTRIBUTIONS

Calculational Model of the VVER-1000 Reactor

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RESEARCH INSTITUTE FOR MEASUREMENT AND COMPUTING TECHNIQUES (MSZKI)

The Research Institute for Measurement and Computing Techniques is devoted mainly to extend computing methods to different fields of application. Our spheres of interest include industrial and measurement applications, business data processing and as a new field, CAD applications. These activities are backed by development of hardware, software and application systems.

Our most important applications are:

— laboratory measurement systems of different complexity;
— development of automatic spectroscopial systems;
— design of the training simulator for a nuclear power plant;
— further development of the computerized nuclear reactor control;
— business data processing, especially in regard to financial transactional systems;
— development of CAD/CAM systems.

Our hardware development efforts are aimed at 16 and 32 bit computers, local networks and peripheral devices. Understandably nowadays there is a growing emphasis on the 32 bit processors, multiprocessor systems and fast, versatile bus systems.

In accordance with the traditions of previous years we continued running our small scale production line — a rather profitable enterprise from a financial standpoint and at the same time a really challenging engineering task.

We were deeply involved in the development of the nuclear reactor training simulator. However this particular topic, due to its exceptional significance is presented separately in this yearbook.

COMPUTER DEVELOPMENT

Our currently produced computers are fully compatible with the industrial standard mini and megamini computers on both the hardware and the software level. The operational systems may be DOS-RV-PLUS, MOS-VP, or in real-time systems MP PASCAL, MOS-VP-ELN.

In the 32 bit processors the memory may be reached by a local 32 bit bus (LBUS).

The main features of the various members of our computer family are listed below:

TPA-11/170 0.5 Mips, 16 bits, 4MB memory, DOS-RV-PLUS, MP PASCAL

TPA-11/171 same as above, but for real-time applications in industrial environment

TPA-11/501 16 MB memory, high performance 32 bit processor for industrial environment. MOS-VP-ELN

TPA-11/510 0.9 Mips, 16 MB memory, MOS-VP, 32 bit processor for general applications

TPA-11/520 a version of the 11/510, where not only the QBUS but the UBUS is also available, increasing the potential for interfacing

TPA-11/530 2.7 Mips,max 64 MB memory, MOS-VP

TPA-11/532 a version of the 11/530, where both QBUS and UBUS are available

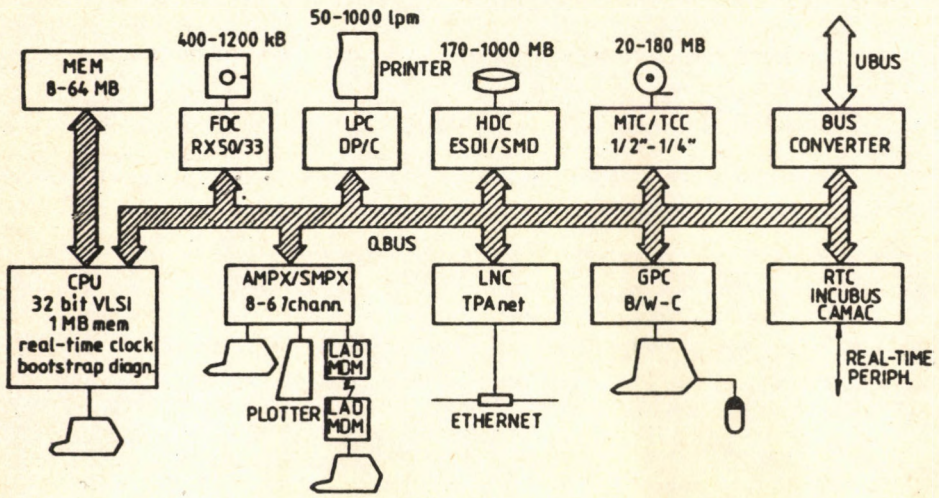

Fig. 1

Architecture of the TPA-11/500 family computers

The block scheme of the TPA-11/500 computers can be seen in Fig.1. The figure gives some information about the standard peripheral devices too. For local networking the use of Ethernet is recommended, with TPAnet (DECnet) protocol. — Real-time equipment may be connected to the computer by the CAMAC system or directly to the QBUS. The MSzKI has a very wide variety of CAMAC modules already developed and in use for several years.

TPA-11/56X Sytem for Multiprocessing

We believe we should mention our newest achievement, the TPA-11/56X VMS compatible multiprocessing system. This high performance architecture has been designed to meet a wide range of requirements in the coming years. A fast, synchronous bus (32/64 bit) connects the powerful system components, memory subsystem modules, industry standard subsystem ports etc.

The immediate Interconnect System Bus — iXbus — steered by a 10 MHz clock signal transfers data at the maximum rate of 80 MBps. A unique priority arbitration system enables the nodes to acquire the iXbus within a very low access time. Distributed arbitration without any dedicated priority logic is a well proven method in parallel processing systems for supporting interprocessor communication. Special interprocessor messages of 100 nsec duration provide an efficient and fast way of multiprocessing administration. The bus adapters can make use of the 32/64 bit data format on the iXbus by buffering word(s) ahead while transferring between memory and I/O ports. This DMA cache facility upgrades the overall throughput.

With the following data we wish to highlight the TPA-11/56X's technical specifications:

System architecture:	iXbus based multiprocessing: max. 4 processors multi I/O: max. 4 bus adapters global memory: max. 128 MB.
iXbus:	4 GB address space 32/64/128 bit data width 80 Mbyte/s transfer capability
Central processor unit:	microprogrammed, 88 bit control word 0.9 Mips/CPU modul 2 × 64 Kbyte cache memory translation buffer of 128 entries.

Apart from the above mentioned projects some other interesting and important developments are going on. Among these we have to mention the research project into finding new methods for fault tolerant computers. We are working on tele-diagnostics and tele-diagnostical expert systems. As a first application there exists a system for the TPA-11/280 computer which tele-diagnoses faults and advises on how to fix them.

COMPUTER APPLICATIONS

CAMAC Systems

Our long and successful past in developing and applying CAMAC systems and components has been continued without a break. Here two new achivements are presented.

We finished the development of a simulator for testing the devices used in a thermonuclear fusion research experiment. The highly sophisticated experimental setup can be tested and checked without the real working of the physical side. — In the centre of the simulator there is a properly programmed crate controller. The analog signals are compared with 1024 sequential samples, synchronously on all the channels. The outputs of the D/A converters are floating. The man-machine interface is provided by an alphanumeric and a quasi-graphic display terminal. The simulated and the measured values may be checked simultaneously point by point.

We finished the development of an IBM-PC family type crate controller. The significance of the PC-s in the experimental measurements is increasing day by day due to the wide spread of these computers — though the PC-s originally were not designed for that purpose.

The mainframe accommodates a PC/CAMAC adapter card, which has the function of connecting the I/O channel of the computer to the HIGHWAY (see Fig. 2). For providing the proper speed this parallel bus is terminated by its characteristic impedance at both ends. The bus is used to connect the CAM 1.40-1 crate controllers of the system to each other and to the PC/CAMAC adapter.

The CAM 1.40-1 controller is housed within a CAMAC module of double width. As a combined crate controller this module allows the realization and use of the DATAWAY, LAM GRADER and AUXILIARY BUS according to the standards written in the EUR6500 Report. During operation 24 bit long CAMAC data words and 17 bit wide commands must be transmitted, this calls for buffer registers within the controller.

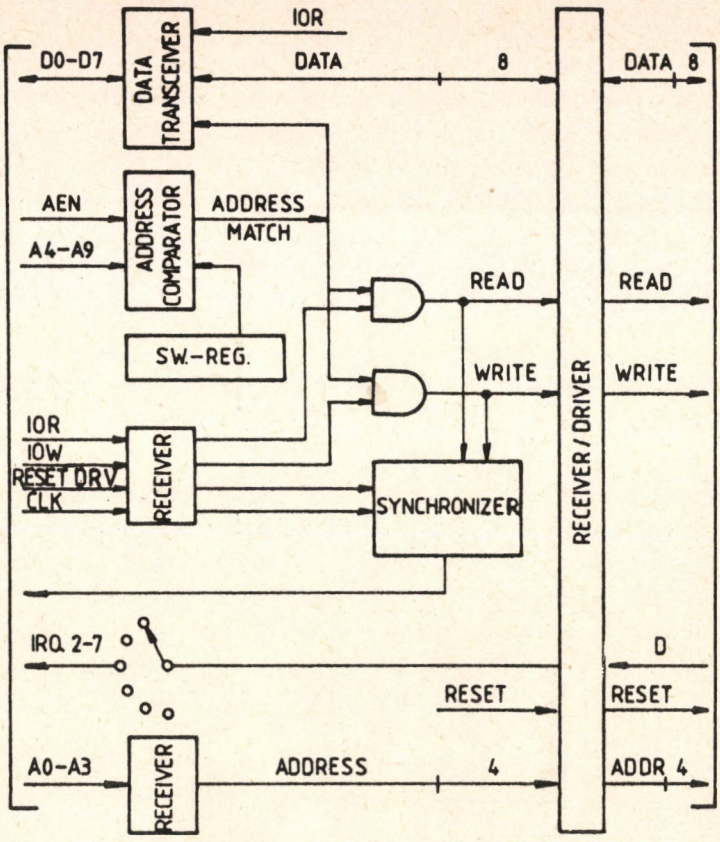

Fig. 2

Block diagram of the PC/CAMAC adapter

As a substantial part of the solution CAMAC has a subroutine package of standard ESONE routines. With these routines CAMAC can be controlled in polling mode as well as in interrupt driven mode. Even memory resident interrupt activated applications are possible with these routines. The DOS device driver is controlled by the operating system. DOS is informed of the current device by means of the configuration file. The user should enter into the CONFIG.SYS the following command:

device=CAMAC.SYS [port address [:interrupt]].

The program handles CAMAC as a peripheral of the operating system, controlling it only by system calls. This is not very fast, but proves to be sufficiently effective with slow, interpreted languages — it suits BASIC best.

In the year 1987 we began a new development for the post CAMAC era. The system under design is hierarchical in itself, with an emphasis on the middle level. Here we intend to use a module system based on the standards of VME. For the lower level, near to the processes and technologies the STE standards are accepted, while for the highest level VAX, MICROVAX standards will be used. We started the development with the following VME modules: Quad Scaler, Parallel I/O Register, Status Change Monitor, Eight Channel S&H Input ADC, Programmable Quad Timer.

Development of Interactive Image Processing System (ATLAS-90)

During the last period the ATLAS 90 interactive image processing system, a joint development of MSZKI and the large cooperative Hiradástechnika, went into production. Its architectural features and main application areas were described in the previous issue of the Yearbook.

The image processing software was produced entirely by our Institute. The system itself is built upon the UNIX timesharing system (version 7).
The main components of the software system are the following:

- user interface
- module library
- function library.

The User Interface ensures two types of access for the user: a menu oriented and a command oriented one.

The Module Library is a set of user programs (commands on UNIX terms), which can be grouped according to their functions:
Image File Handling: these modules transfer image files between the system and the outside world, or within the system between different storage media.
Screen Display Control: these modules are responsible for screen definition, assignement of image memory areas to screens, changing displaying parameters interactively.
Image Prosessing Modules: these consist of several subgroups, such as programs for

- preprocessing images (filtering, smoothing, etc.)
- calculations of image statistics
- Fourier and inverse Fourier transformation
- filtering in spectral domain
- supervised classification
- clustering (unsupervised classification)
- image arithmethics.

The above collection of programs is of course incomplete, several general purpose or specific functions will be added in the future.

The third main component is the Function Library, consisting of all image memory and device handling functions used in the development of the modules. Because of the efficiency requirements some of the functions have to use the microcoded special instructions of the IPC controlling computer.

CAD/CAM Systems on TPA Computers

TPA computers with 32 bit central processing units have opened the way to the application of big CAD systems. The increased throughput of the TPA-11/540 and TPA-11/580 computers aided by the MOS-P operational system makes feasible the running of programs with exess need of calculations, such as CAD systems.

Currently four big systems for mechanical design are in use. Engineering/construction is aided by two of them. The third one helps to prepare a finite-element-analysis program, the fourth does the analysis.

The engineering package (CAD-E) is a three dimensional body modelling system. The three dimensional model of an object can be designed easily by a series of set-operations on previously defined geometrical elements. The model developed may be used as a data base generating a technical drawing, an NC program etc.

The finite-element-analysis packages (CAD-P and CAD-F) serve for the preparation of the geometrical model, the optimization, the graphical display, the interface with other systems, and of course the analysis itself.

Examples of display outputs generated by the system can be seen on Fig. 3.

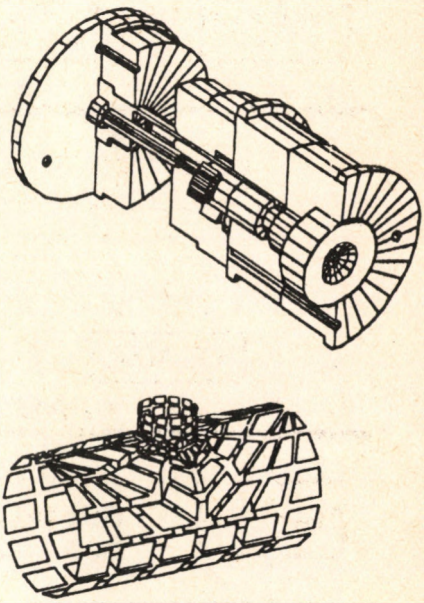

Fig. 3

Display outputs of the CAD/CAM system

Local Area Networks

The development of the LOCHNESS local area network has been finished and now it is used in two big systems — one in our Institute and one in the Kurchatov Institute (Moscow).

The main features of the system are: it is compatible to DECnet with 1 MBps transmission rate, modified CSMA/CD technology. Intelligent CAMAC crate controllers and computers with unibus can be used under RSX-11M/M+ operational system (Fig. 4).

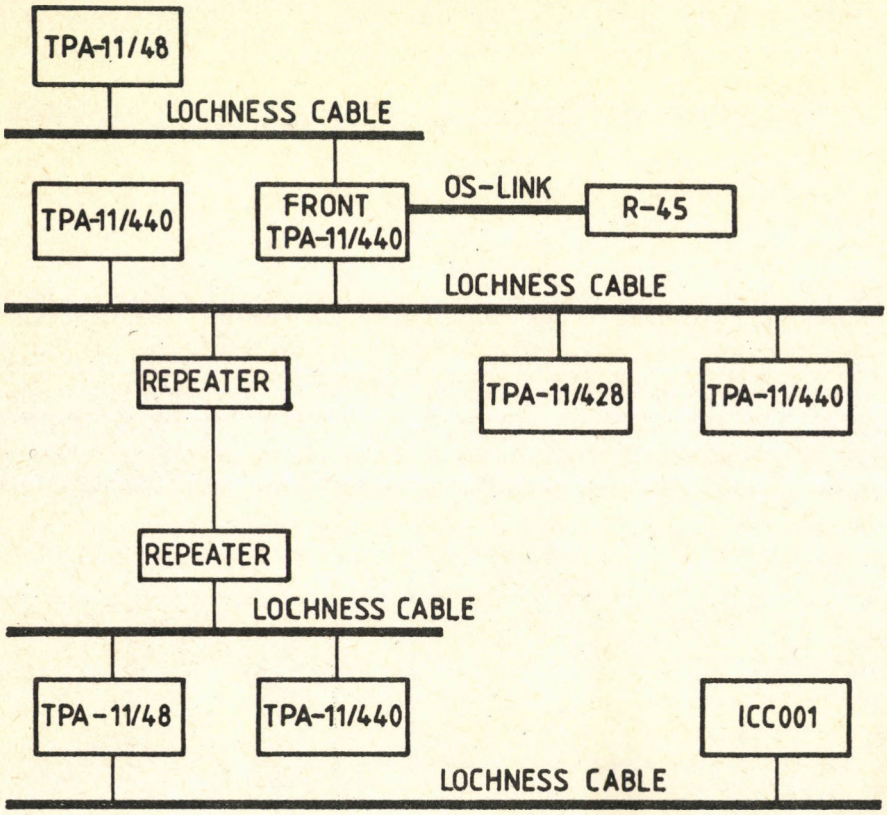

Fig. 4

Overview of the lochness local area network

The application fields of the system proved to be significantly less than was planned. However, we judge our experiences with Lochness really valuable in that they give us a firm base in the development and future use of the Ethernet system.

As building elements of our data network system we developed some optical fiber devices. Transmitters, receivers, transceivers, multiplexers are already in use. Their range is approximately 2.5 kilometers and they work from DC to 20 Mbaud. The multiplexer handles eight RS-232 channels.

Speaking Computer for the Blind

Designing computers for disabled people, especially for the blind is an unusual and challenging task. In the recent years a talking personal microcomputer was developed in our Institute. A Z80 based microcomputer was modified so that even the screen editing system can be used by visually handicapped people.The computer with its talking BASIC and talking assembler/disassembler proved to be a success.

The advanced version is called BraiLab Plus. This machine is supplied with a talking version of CP/M compatible operating system. A talking text editor and a talking data base system is ready to use. The BraiLab was aimed at helping professionals working with computers. It is transportable. The speech synthetyzer is integrated into the computer.

Text-to-speech systems are language specific. A Hungarian speech system has not been available on the market. Therefore a research was carried out in the field of formant analysis and synthesis for the Hungarian and German languages (in cooperation with the Linguistic Institute of the Hungarian Academy of Sciences). — Many problems in the development of the project, which heretofore could only have been resolved with the help of semantic analysis were simplified with the introduction of an intermediate Braille coding system. — The low cost MEA 8000 formant synthetizer was used, which is capable of producing any language.

A blind research worker also took part in the process of the development so human engineering aspects were always considered, respected and promptly tested. — A user with a reasonable tempo of voice output can achieve about 320-350 words/minute reading speed, which is faster than using Braille. The talking computer is especially useful for those people who lost their sight in their adulthood, because they read Braille very slowly.

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COMPUTING CENTRE (SZK)

Computing Services

As its main activity, the Computing Centre provides computing services for the entire Institute and carries on scientific research in the field of numerical and non-numerical applications of computers and in mathematical physics.

After eleven years of use, the ES 1040 computer was replaced in 1988 with a BASF 7/61. The ES 1045 computer, purchased in 1986, is still in operation. The configuration of the new BASF 7/61 mainframe is as follows:

— Central processing unit with 3 Mbyte memory,
— 2 × 280 Mbyte Winchester type disk units,
— 4 × 70 Mbyte Winchester type disk units,
— 3 magnetic tape units with recording density of 1600 bpi,
— 2 line printers,
— a local terminal controller with 16 terminals.

Both computers are IBM compatible, and run under the OS/VS1 operating system. Thus a reasonable division of the workload between the computers can be achieved.

In the recent years a number of personal computers, mostly IBM compatible, have been installed in the Institute. There is an increasing tendency of using these as terminals and for transferring files to and from the disk storage of the mainframes. There are two ways of doing this. Some of the PC-s are connected to the local area network of the Institute and others directly to the central computers. The file transfer facility has been used intensively to exchange data files and download programs.

The development of an Ethernet type network extending the services of the existing LOCHNESS one is now in progress. The network is interfaced to the central computers through the TPA 11/440 front-end machine, making further services of the Computing Centre available to all computers connected

to the network. The connection to the X.25 wide area packet switching network will also be in operation from 1989, thereby integrating the databases housed in the hosts of the network into a unified system.

The program library contains compilers for the languages VS FORTRAN, FORTRAN, COBOL, PL/I, PASCAL (AAEC version) and such subroutine libraries as CERN library, IMSL library, EISPACK, Harwell and Rutherford libraries and the Computer Physics Communications program library.

Interactive compilation and execution of programs are possible under GUTS (Gothenburg University Time-sharing System). The following interactive compilers and interpreters are available:

- BASIC interpreter,
- Waterloo FORTRAN compiler for the debugging of FORTRAN programs,
- BMDP program package for statistical analysis of data in medical and other laboratory researches,
- REDUCE 3.3 computer algebraic language together with program packages for various applications, e.g.
- GENTRAN, an interface to the FORTRAN language,
- EXCALC, a package for exterior calculus,
- ALGINT, a package for analytic integration of expressions involving square roots.

Computer Applications

In the field of non-numerical applications a data base development project for information storage and retrieval is on its way. For several years, the processing of a bibliographical data base containing the data of the research reports in the Central Library of the Institute has been carried out by a program package developed by the Computing Centre. That package has produced several types of catalogues in batch mode (list of current acquisitions, yearly catalogues by authors etc). The data base was redesigned and re-built in 1988. The processing is now performed by the CDS/ISIS data base management system for online information retrieval developed and distributed by UNESCO. The design and the processing of other bibliographical data bases (e.g. books, periodicals, programs in the program library) are also in progress.

Methods of computer algebra have been applied to solve a number of problems in rational approximations of functions, in theoretical physics and in theoretical biology.

Computer simulation was performed to model the local structure of liquid water. Random molecule configurations were generated by Monte Carlo methods and the eigenvalues of the vibrational Hamiltonian have been used

to obtain stretching frequency probability distributions of liquid water. Anharmonicity of vibrations has been taken into account by applying a suitable series approximaton to the interaction potential function.

In cooperation with the Institute of Atomic Energy, subprograms were developed for the KARATE and TICMOS-1 program systems. KARATE models and simulates VVER-1000 nuclear power reactors and the software TICMOS-1 supports users of a modular program system in data and program handling. The program PREMOS helps TICMOS-1 users to prepare data interactively. By applying numerical methods, convergence of some matrix iteration techniques were accelerated for programs of the KARATE system. This has also been done to the CYLAN code for solving linear systems of equations. For finding the largest eigenvalue and eigenvector of a large sparse matrix, an improved Arnoldi method, which is optimal among polynomial methods, has been developed for the HEXEIS program. Moreover, the inner and outer iterations have been tuned for a more effective performance.

In a joint effort with the researchers of the Department of Plant Taxonomy and Ecology and the Department of Genetics at the Eötvös Loránd University, evolution of species has been simulated by solving a varying number of nonlinear stiff differential equations.

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G. VIDA* , E. SZATHMÁRY* , G. NÉMETH, Cs. HEGEDŰS, P. JUHÁSZ- NAGY* , I. MOLNÁR*: Towards modeling community evolution: The Phylogenerator. In: Organizational Constraints on the Dynamics of Evolution (eds. Vida G. and Smith J.) Manchester University Press 1988

DEVELOPMENT ENGINEERING (MSZI)

The central technical base of KFKI, the Development Engineering Division (MSzI) continued its activities during 1987-88 in developing and manufacturing high-quality mechanical equipment and electronic systems. Apart from this work, fundamental and applied research is also being conducted in certain fields of techniques and technology.

The upkeep of some of KFKI's infrastructure, which includes energy supply installations, is part of the maintenance responsibility of this division.

Some of the more important activities carried out during the last two years are described below.

Equipment for Research Reactors

A. Baranyai, A. Gossányi, L. Hományi, J. Kovács, Gy. Máday, A. Rényi, Gy. Szántói, J. Zsidó

The pneumatic post system, designed to transfer samples, forms an integral part of nuclear reactors used for isotope production and/or activation analysis: since these pneumatic posts are directly linked with the active zone. Because radioactive samples are often transferred, in order to avoid human contact an electronic system had to be developed which includes:

— a digital neutron flux measurement system,
— a multichannel dosimetric measurement system,
— a controller for the pneumatic transfer system.

Digital neutron flux measurement system

The main operational and physical parameters of the nuclear reactor are determined by processing the signals of the SPND (Self Powered Neutron Detector) placed inside the zone and by the fission and ionization chambers outside the zone. Signal processing is performed by a microprocessor-based instrument family consisting of up-to-date circuit elements.

Development has resulted in the following devices:

5-channel mean-power measurement setups,
automatic power controller,
digital reactivity meter.

Multichannel dosimetric measurement system

The system is designed to measure the radiation level by processing the signals of the detectors which are sensitive to neutron, gamma and beta radiation. The Dosimetric Measurement System type FA-01.03 can process signals from 10 detectors. GM counters,gamma ionization chambers, BF_3 tubes and scintillation sensors can be used as detectors.

Controller for the pneumatic transfer system

The irradiation points, the low background measurement points — often with semiconductor detectors — the sample holders and the decomposition boxes are generally linked by a pneumatic post with a complex configuration.

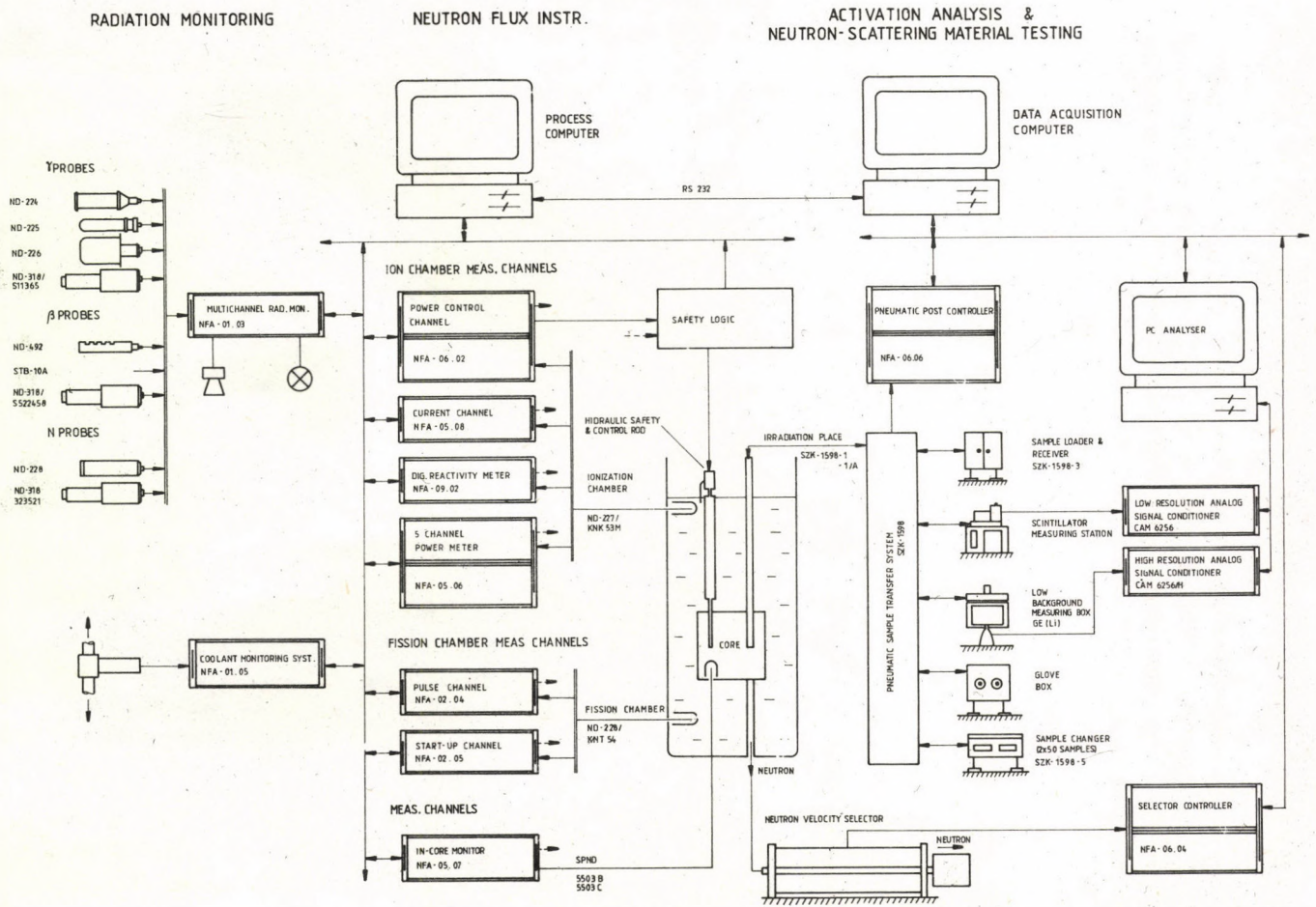
The most important functions of a programmable controller (after the usual parameters are fed in) are:

— to activate the pneumatic valves according to the order and timing needed for the measurement task,
— to detect, display and acknowledge the signals of the photoelectric cells which indicate the actual position and code of the samples,
— to store the information and parameters necessary for evaluation and measurement.

The structure of the Dual Processor Controller, type NFA-06.06 follows the most up-to-date reactor-technique guidelines for the eighties.

In addition to the control functions, the NFA-06.06 performs self-checking, display and software backup for complex data traffic.

REACTOR INSTRUMENTATION



The new system (see block diagram) has many advantageous features:

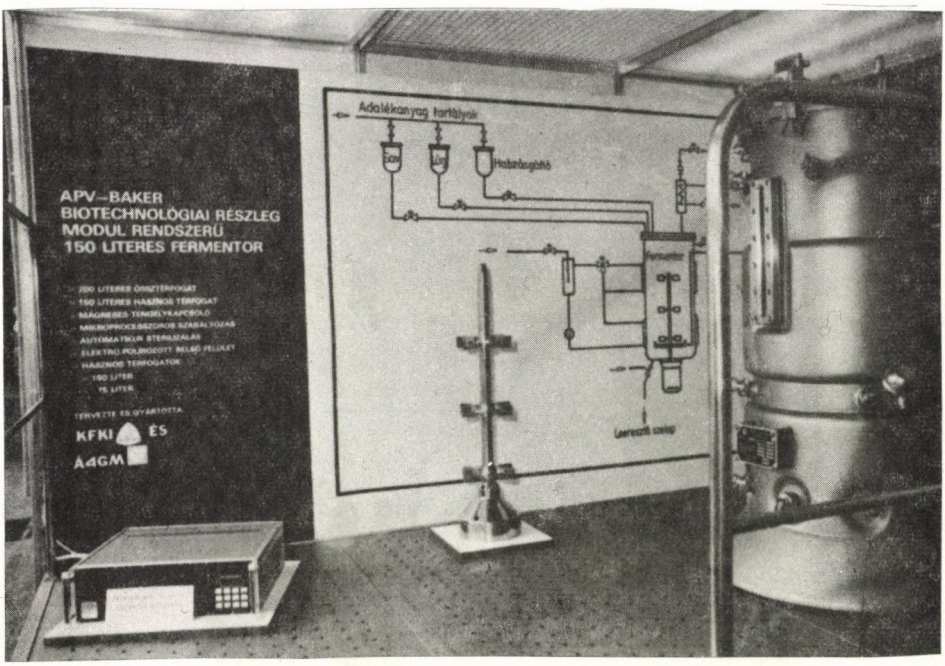
- the whole electronic system of the reactor and the pneumatic transfer systems are built up of the same type of circuit elements;
- the reactor technique, dosimetry and pneumatic system parameters can be displayed on the computer screen, thereby assisting the work of the operator;
- direct access is provided to the neutron flux values necessary for activation analytical calculations;
- the internal radiation protection system of the reactor and the work stations where isotopes are measured.

250/150 Litre Pilot Fermentor System

B. Bak, Gy Baksa, M. Danka, B. Egri

This fermentor system was developed for laboratories, universities and industrial applications.

The fermentor vessel — as concerns its size and material — meets the recommendations of the DECHEMA operator standards. The vessel with the auxiliary supply systems, the rack containing the measurement and the elec



tronic and pneumatic control modules are mounted on a firm chassis using an open-frame technique. The system and all of its units — pipe, filters, valves etc. — can be sterilized in situ,individually or together, either automatically or manually.

The more important tasks of the electronics are: the sequential control of sterilization, fermentation, filling and draining processes; the control of the pO_2, pH foam level, of the temperature of the liquid and of the speed of the agitator; the measurement of the liquid weight and of the off-gas O_2 and CO_2 content.

The control system is based on a dual microprocessor unit. Normally the first processor controls, while the second one checks its functions and is able to take control in case of an error or malfunction. The agitator is rotated by a frequency-controlled AC motor. The man-machine interface consists of an LCD display with a keyboard and a mimic diagram. The system is connected to an IBM-AT compatible computer, which displays 480 x 128 dots and stores the measured values of the parameters of the fermentation process.

This intermediate production system is suitable for studying scale-up and other production problems between bench-scale experiments and full commercial production.

Applications of Space Developments for Railway Statistical Energy Analysis

M.F. Ránky, G.T. Endrőczy, J. Tombor

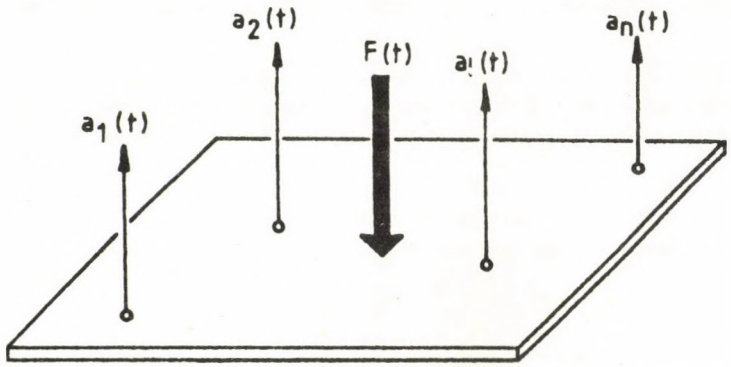
Previous work in the random vibration analysis of satellite structures resulted in a set of practically applicable techniques such as the detailed analysis of frequency band average loss factors of plates and shells, and the study of modal densities of special structural elements. Furthermore, the matrix iteration method was used for in situ identification of assembled complex structures.

The diagnostics capabilities developed in space research are applied at the Hungarian State Railways. It was found that railstock wheeldisc—tyre separation can be detected using frequency band average loss factor measurements. The railway industry benefits from this application through a reduction in costs attributable to increased reliability and availability. A portable instrument was built on the basis of experimental results to perform the in situ diagnostic measurements.

The Statistical Energy Analysis method is a generalized technique for the estimation of the average vibration levels in a structure excited by broad-band random forces. The investigated structure is idealized in a group of individual subsystems. Energy dissipated by a subsystem is characterized by the loss factor and that which is transferred to connected subsystems by the couplig loss factor. Early experiences gained from the experiments on satellite structures [1-5], have shown that the loss factor of a subsystem is very sensitive to structural details, therefore it has to be considered to be a good diagnostic element.

Measurement of the loss factor by the energy method

A detailed study of the various ways of measuring of the loss factors was carried out at ISVR in Southampton [3]. The energy method developed for experimental work is shown in Fig.1. A direct power input technique has



$$\eta(f) = \frac{1}{f_2 - f_1} \int_{f_1}^{f_2} \frac{F^2(t)\,\mathrm{Re}(Y)\,2\pi f}{\langle |a(i\omega)|^2 \rangle\, mA}\, df$$

Fig. 1

Experimental determination of the frequency band average loss factor using the energy method developed in earlier work [3].

SYMBOLS: F - driving force, P - direct power input, f - frequency(Hz), a - surface acceleration, v - surface velocity, m - mass/unit area of structure, Re - real part of..., t - time, η - loss factor, $\langle\ \rangle$ - spatial average

been used to measure the driving force (F) and the real part of the mobility (Re/Y/). The energy stored is estimated from spatial average surface velocity which is obtained from seperate accelerometers (see formula in Fig.1). Fig.2 gives an idea of how effective the method can be in measuring or "diagnosing" slight changes in the damping conditions of a structure.

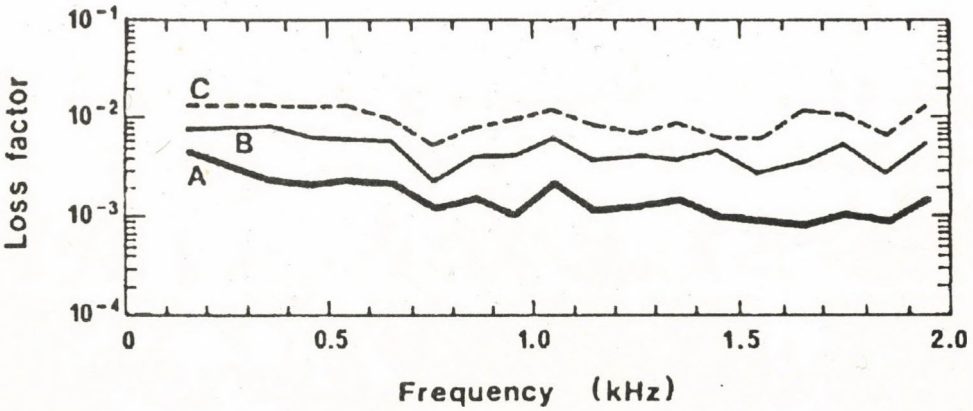


Fig. 2

Frequency band average loss factors for three different damping conditions of a flat plate

A: undamped flat aluminium plate
B: self-adhesive damping tape applied to two opposite sides of the plate
C: self-adhesive damping tape applied all around the periphery of the plate

Railway wheeldisc-tyre separation diagnostics

Early detection of railstock wheeldisc—tyre separation is an important issue for the railway. Up to now no quantitative in situ nondestructive techniques were available. Frequency band average loss factors of wheeldisc—tyre subsystems were measured for a number of wheelsets in various stages of separation. It was found that the obtained loss factors were very sensitive to the various fit conditions. Four typical curves are shown in Fig.3. The frequency band around 3kHz is the most characteristic of the various fit use conditions which maintenance people of the railway industry are interested in. Thus a special portable instrument was subsequently built for regular in situ diagnostics applications.

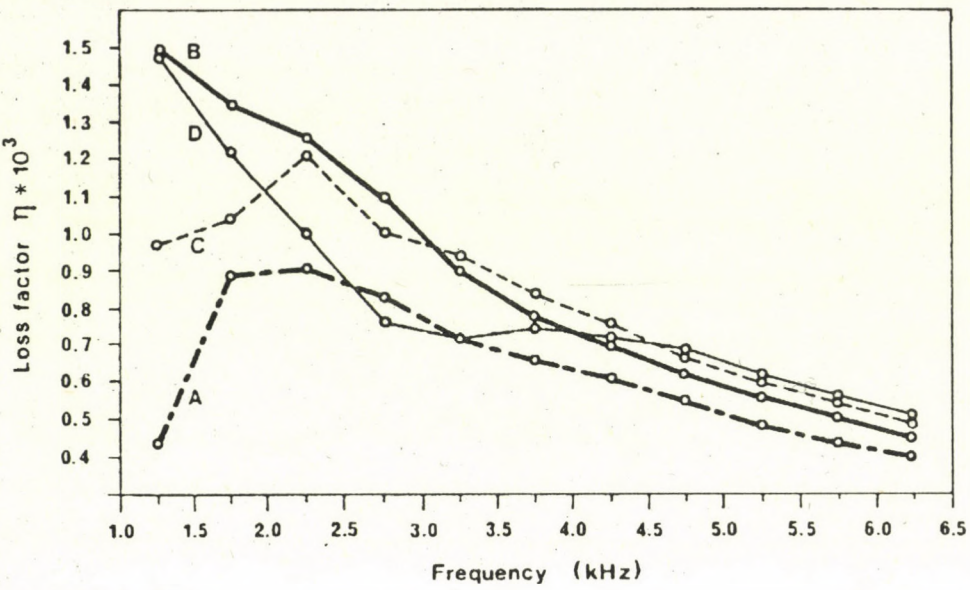


Fig. 3

Frequency band (500 Hz) average loss factors of four individual shrinkfit tyre railway wheels

A: wheeldisc—tyre fit in acceptable, good condition (go)
B: wheeldisc—tyre fit in an unacceptably poor condition (no go)
C: wheeldisc—tyre slippage, fit unacceptable (no go)
D: very high mileage wheel, though tyre fit still acceptable (go)

Acknowledgements

The author wishes to thank the Hungarian State Railways for the sponsorship of this work done under contract.

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M. DANKA, L. HÁZKÖTŐ, A. MAJOROS: High pressure oxidizing furnace for dry and wet oxidizing operations. I. European Conference on Industrial Furnaces and Boilers 21-24. March, Lisbon, Portugal (1988)

Patents

G. BAKSA, A. BARANYAI, Z. ÓDOR, J. PERENDI, A. RÉNYI: Equipment suitable to monitor and control rotating disc and drum mechanical systems to ensure their safe operation

A. BARANYAI, L. HOMÁNYI, G. MÁDAI, J. ZSIDÓ: A switching arrangement suitable for a gradually changing, small/minute increment digital reactivity measurement

CENTRE FOR INTERNATIONAL WORKSHOPS IN THEORETICAL PHYSICS (NEFIM)

The workshop centre of the Hungarian Academy of Sciences was established in 1983.

The Centre for International Workshops in Theoretical Physics (NEFIM) is jointly supervised and sponsored by the Hungarian Academy of Sciences and by the Central Research Institute for Physics, Budapest (KFKI).

NEFIM acts as an institutional framework for organizing workshops of (1 to 6 weeks) for Hungarian and foreign physicists intent to solving problems in definite areas of theoretical physics by way of intensive exchange of information.

From 1987 onwards, NEFIM sponsors two fellowships in theoretical physics. These fellowships are advertised for foreign applicants, for a period of six months. The posts are made available at KFKI and/or the Eötvös University, Budapest (ELTE), in accordance with the research area of the successful applicant.

The Hungarian Academy of Sciences allots a certain annual budget to cover the expenses of invited foreign scientists during their stay in Hungary.

In addition, KFKI provides NEFIM with office rooms, a conference room and the requisite equipment. NEFIM is also authorized to use the infrastructure of KFKI such as the library, the publication service, the Department of International Relations and 150 hours/year of machine time on the central computer of KFKI.

Other institutes and universities also assist NEFIM and its activities by loaning conference rooms and various other facilities. A survey of workshops held in the years 1983 through 1988 together with the names of the workshop directors is appended.

NEFIM WORKSHOPS 1983-88

1983

Relativistic Nucleus-Nucleus Collisions (J. Zimányi)

Electric Fields in the Cometary Environment (K. Szegő)

Quantum Chromodynamics on the Lattice (A. Patkós)

1984

Charge Density Waves in Solids (J. Sólyom)

Stochastic Systems; Mathematical Methods in Statistical Physics (L. Szász)

Properties of Chaos (P. Szépfalusy)

Testing QCD in High Energy Hadronic Reactions (G. Pócsik)

Dynamic Phenomena in Neurochemistry and Neurophysics (P. Érdi)

1985

Chaotic Phenomena and Related Subjects (P. Szépfalusy)

Dynamics of Few Body Systems (Gy. Bencze)

Hadron Structure (E. Nagy)

Theory of Relativity (F. Károlyházy)

Microcomputers in Science (G. Marx)

1986

High Energy Heavy Ion Collisions (J. Zimányi)

Infrared Divergences in the Physics of Condensed Matter (A. Zawadowski)

Nonperturbative Methods in Quantum Field Theory (Z. Horváth)

1987

Chaotic Behaviour of Nonlinear Systems (P. Szépfalusy)

Collision of Relativistic Heavy Ions (J. Németh)

Star Pulsation with Multiple Period (B. Szeidl)

Separable Interactions in Quantum Mechanics (J. Révai)

The Theory of Relativity (Z. Perjés)

Standard Model and the High Energy Hadron Reactions (G. Pócsik)

The Formation of Galaxies (G. Marx)

1988

Non-Perturbative Methods in Field Theory (A. Patkós)

Relativistic Heavy Ion Reactions* (J. Zimányi)

Nuclear and Subnuclear Few Body Problems* (I. Lovas)

Complex Systems** (N. Menyhárd)

Models of the Neural System** (T. Geszti)

Relaxation in Ordered Matter (I. Tüttő)

* Held simultaneously

** Held simultaneously

LIST OF KFKI REPORTS 1987-88

KFKI-1987-01/A V.Sh. GOGOKHIA*, B.A. MAGRADZE*: Nonperturbative approach to quark propagator in the covariant, transverse gauge

KFKI-1987-02/M M. BARBUCEANU*, S. TRAUSAN-MATU*, B. MOLNÁR: Integrating declarative knowledge programming styles and tools for building expert systems

KFKI-1987-03/G L. SZABADOS, Gy. ÉZSÖL, L. PERNECZKY: Primary loop dynamical investigations. Part 1. Computerized analysis of the total loss of flow in the Paks NPP on the basis of PMK-NVH experimental data (in Hungarian)

KFKI-1987-04/G Gy. EGELY: Critical comparison of nuclear safety reports. Part 1. Practice followed in the USA and in FRG (in Hungarian)

KFKI-1987-05/G Gy. ÉZSÖL, G. BARANYAI, V. CSOM, E. MAETZ, L. MARÓTI, I. NAGY, L. PERNECZKY, L. SZABADOS, I. TÓTH, I. TROSZTEL, F.VASENSZKY, P. WINDBERG: A 7.4% cold leg break without SIPs. Description of the measurement (in Hungarian)

KFKI-1987-06/G Gy. ÉZSÖL, G. BARANYAI, V. CSOM, E. MAETZ, L. MARÓTI, I. NAGY, L. PERNECZKY, L. SZABADOS, I. TÓTH, I. TROSZTEL, F.VASENSZKY, P. WINDBERG: Primary loop dynamical investigations. Part 1. Experimental investigation of the total loss of flow in the Paks NPP in the PMK-NVH facility (in Hungarian)

KFKI-1987-07/G L. SZABADOS, E. BIRÓ, Gy. ÉZSÖL, L. MARÓTI, L.PERNECZKY, I. TÓTH, I. TROSZTEL, J. VIGASSY: A calculation method for the operation of the Paks NPP based on the subchannel approach. Part 1. A computing procedure and method applicable as part of the VERONA system (in Hungarian)

KFKI-1987-08/B L.B. SZABADOS: Commutation properties of cyclic and null Killing symmetries

KFKI-1987-09/E G. GYÖRGYI*, P. SZÉPFALUSY: Relaxation processes in chaotic states of one dimensional maps

KFKI-1987-10/D Gy. EGELY: Hungarian ball lightning observations (case 1-case 278)

* The author is not a member of the KFKI staff

KFKI-1987-11/M H. KÖNIG: Developing protocol test software using the PDL-system

KFKI-1987-12/M D. NICHOLSON, B. MOLNÁR: Advanced help through plan instantiation and dynamic partner modelling

KFKI-1987-13/M K. TARNAY, M. BOHUS*, J. HARANGOZÓ*, P. TŐKE*, I.FÜVESI*, I. KOVÁCS, K. VARJU*, M. TÓTH ABONYI*, P. HUNYA*: Experiments with a network environment manipulator (in Hungarian)

KFKI-1987-14/A H. W. BARZ*, B. KÄMPFER*, B. LUKÁCS, K. MARTINÁS*, Gy. WOLF: Deconfinement transition in anisotropic matter

KFKI-1987-15/M R. WITTMANN: An algebraic specification method for describing the protocols of computer networks (in Hungarian)

KFKI-1987-16/G O. AGUILAR*, G. PÓR: Monitoring temperature reactivity coefficient by noise method in a NPP at full power

KFKI-1987-17/M Collection of scientific papers in collaboration with Joint Institute for Nuclear Research, Dubna, USSR and Central Research Institute for Physics, Budapest, Hungary. Algorithms and programs for solution of some problems in physics. Fifth volume. (Eds.: G. NÉMETH, Ju.Ju. LOBANOV*)

KFKI-1987-18/E G. EGELY, G. VÉRTESY: Experimental investigation of biologically induced magnetic anomalies

KFKI-1987-19/A B. MILEK*, R. REIF*, J. RÉVAI: A model for particle emission from a fissioning system

KFKI-1987-20/M S.WAGNER-DIBUZ: The specification and testing of transport protocols (in Hungarian)

KFKI-1987-21/E B. LUKÁCS, K. MARTINÁS*: Elementary quantum physical description of triplet superconductors

KFKI-1987-22/G M. MAKAI, J. GADÓ, A. KERESZTÚRI: DIGA/NSL - New caloculational model in slab geometry

KFKI-1987-23/A J. ERŐ, Z. FODOR, J. FRANZ*, J. KECSKEMÉTI, P. KONCZ, Zs. KOVÁCS, E. RÖSSLE*, C. SAUERWEIN*, H. SCHMITT*, Z. SERES, H.L. WOOLVERTON*: Production of protons, deuterons and tritons on carbon by intermediate energy neutrons

KFKI-1987-24/K I. BALÁSHÁZY, G. SZABADINÉ-SZENDE, M. LŐRINC, P.ZOMBORI: Gamma-spectrometric examination of hot particles emitted during the Chernobyl accident

KFKI-1987-25/K A. ANDRÁSI, I. NÉMETH, P. ZOMBORI: Application of Ge-spectrometry for rapid in-situ determination of environmental radioactivity

KFKI-1987-26/G J. VÉGH: Neutron spectrum measurement in the channel No. 182/5 of the KFKI WWR-SM reactor

KFKI-1987-27/A S. KRASZNOVSZKY, I. WAGNER: Universal description of inelastic and non(single)-diffractive multiplicity distributions in pp collisions at 250, 360 and 800 GeV/c

KFKI-1987-28/M F. ADORJÁN, J. BÁNÁTI, L. BÜRGER, G. KÁNTOR, A.KERESZTÚRI, L.SZABÓ: VERONA plus extended core monitoring system for WWER-440 type nuclear power plants

KFKI-1987-29/G J. VÉGH, W.L. ZIJP*, H.J. NOLTHENIUS*, G. ALLOGGIO*, E. BREGA*: Application of boron filters for neutron spectrum determination purposes in various neutron environments

KFKI-1987-30/E N. MENYHÁRD: Inhomogeneous mean field approximation for phase transitions in probabilistic cellular automata — An example

KFKI-1987-31/M G. NÉMETH, M. ZIMÁNYI: Computation of generalized Padé approximants

KFKI-1987-32/E I. PÓCSIK: Lone-pair model for high temperature superconductivity

KFKI-1987-33/B L.B. SZABADOS: Causal boundary for strongly causal space-time

KFKI-1987-34/A Z. FODOR, Zs. KOVÁCS: Proton detection efficiency of a plastic scintillator telescope

KFKI-1987-35/C R.Z. SAGDEEV*, K. SZEGŐ: Near nuclear region of comet Halley based on the imaging results of the VEGA mission

KFKI-1987-36/E Gy. SZABÓ: Thermodynamic aspects of chemically curved crystals

KFKI-1987-37/A T. NAGY*, P. VECSERNYÉS: Lepton → lepton + photon decays and lepton g 2 factors in gauge theories

KFKI-1987-38/K S. DEME, E. LÁNG, Gy. NAGY: Real-time computing in environmental monitoring of a nuclear power plant

KFKI-1987-39/K L. KOBLINGER: A review of Monte Carlo techniques used in various fields of radiation protection

KFKI-1987-40/A J. BALOG, P. FORGÁCS, P. VECSERNYÉS, Z. HORVÁTH*: Lattice classification of the four-dimensional heterotic strings

KFKI-1987-41/E I. FURÓ, A. JÁNOSSY: Evidence of antiferromagnetic ordering in La_2CuO_4: re-interpretation of ^{139}La nuclear quadrupole resonance (NQR) data

KFKI-1987-42/J Á. VÉRTES, P. JUHÁSZ, P. JANI, A. CZITROVSZKY: Kinetic energy distribution of ions generated by laser ionization sources

KFKI-1987-43/E Z. JUHÁSZ: Variations of the transfer function during $Bi_4Ge_3O_{12}$ growth

KFKI-1987-44/G A. GÁCS, J.S. JÁNOSY, Zs. KISS: Simulation of the dynamic behaviour of the secondary circuit of a WWER 440 type Nuclear Power Plant. Part 1

KFKI-1987-45/M,N H. KOENIG*, K. TARNAY: An intelligent protocol workstation

KFKI-1987-46/M,N P.ECSEDI TÓTH, K.TARNAY: Formal description oriented performance evaluation of protocols

KFKI-1987-47/A N.P. ALESHIN*, S.L. BELOSTOTSKY*, Yu. V. DOTSENKO*, O.G. GREBENYUK*, L. M. KOCHENDA*, L. G. KUDIN*, N. P. KUROPATKIN*, S.I. MANAYENKOV*, O.V. MIKLUKHO*, V.N. NIKULIN*, O.E. PROKOFJEV*, A.Yu. TSAREGORODTSEV*, S.S. VOLKOV*, J. ERŐ, J. KECSKEMÉTI, Zs. KOVÁCS, Z. SERES: Study of proton-deuteron break-up reaction in exclusive experiment at 1 GeV

KFKI-1987-48/E B. SAS, T. KEMÉNY, J. TÓTH, F.I.B. WILLIAMS*: Scattering mechanisms and transport properties of FeTMB amorphous alloys

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150