YEARBOOK

CENTRAL RESEARCH INSTITUTE for PHYSICS

OF THE HUNGARIAN ACADEMY OF SCIENCES

MTA KFKI

1979-80

YEARBOOK
1979-80

MTA • Központi Fizikai Kutató Intézet

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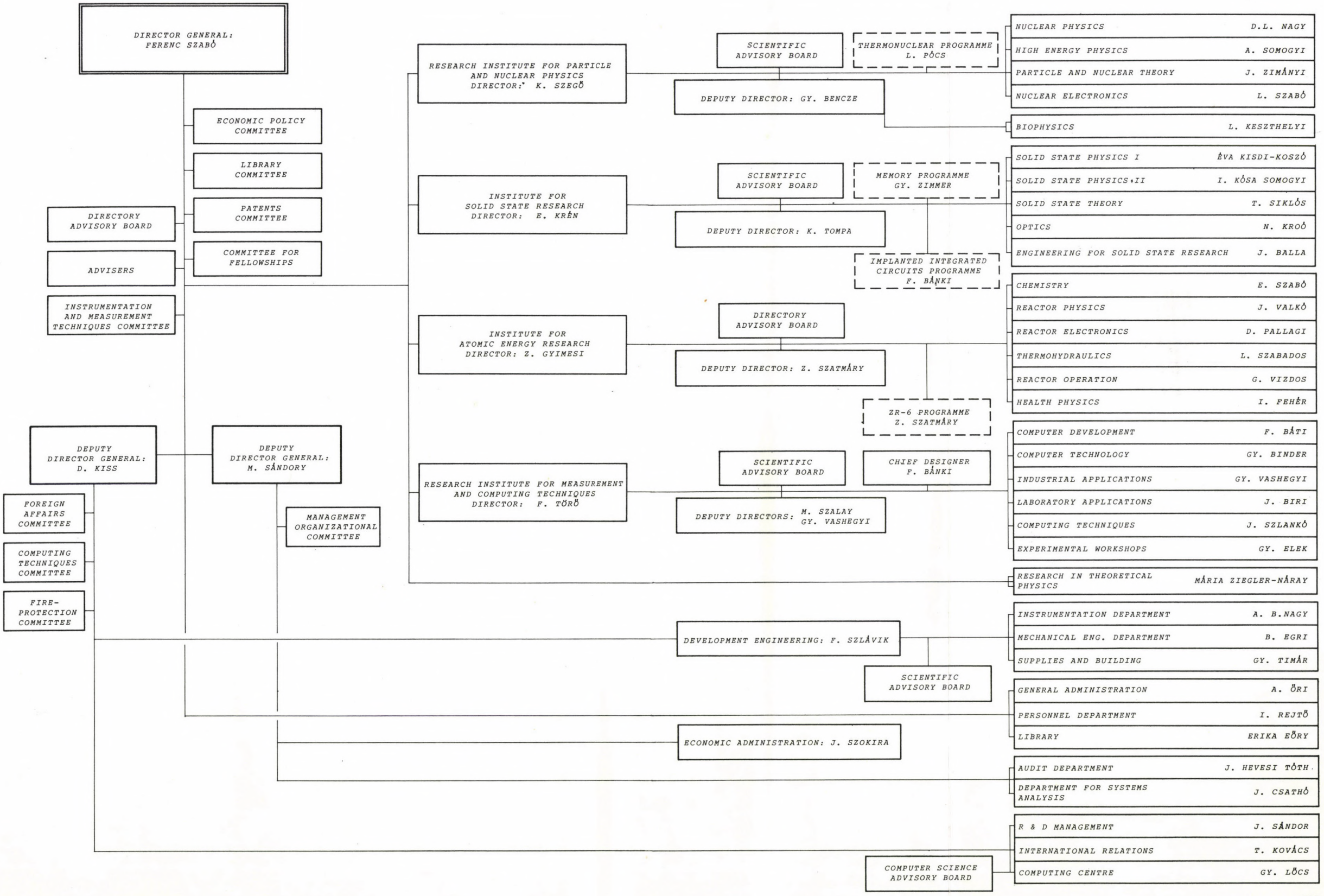
EDITORIAL NOTE

After a one-year break our readers can again take into their hands our Yearbook which will be published biennially in the future and will thus cover the results of research and development over a two-year period. Apart from its being published every second year there are some minor changes the most significant being that the Yearbook now includes a complete List of Publications. The separate publication of this booklet has accordingly been discontinued as has the listing of the publications following the topics in the Yearbook. The system that is now followed is that after each research topic the serial number — taken from the List of Publications — of the relevant research papers will be given. It is hoped that the Yearbook in its slightly changed format and with the new publication schedule will continue to provide our readers with information on the research activities and results obtained in our Institute.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RELATIVITY AND ASTROPHYSICS

P. Forgács, B. Lukács, Z. Perjés, Á. Sebestyén

In collaboration with researchers of the University of Oxford, Oxford, England, we have continued the research work in twistor theory which is related primarily to applications in particle theory. We constructed a 3-twistor model of the low energy hadrons. The internal symmetries of 4-twistor systems have been found. We established a description of the internal states of the particles in 3-dimensional complex space.

Within the framework of general relativity, we initiated an investigation of solutions with null Killing vectors. We have shown that the spin coefficient equations are greatly simplified in this case. A new solution has been obtained, representing a coupled Einstein-Maxwell system having a null Killing vector. This work is being continued in the hope of solving in general the coupled Einstein-Maxwell equations of light-like symmetry.

We continued the investigation of some problems in relativistic hydrodynamics and thermodynamics.

In the theory of SU(2) gauge fields, classical self-dual solutions have been studied. A correspondence between the Ernst equation of general relativity and gauge field equations has been established. It has been shown that the Atyiah-Ward-Drinfeld-Hitchin-Manin theorem based on compactifying Euclidean space, though mathematically correct, uses an inappropriate assumption.

PUBLICATIONS: 71, 73, 74, 94, 222, 223, 224, 225, 272, 273, 274, 275, 276, 277, 301, 302, 418, 429, 489, 556, 601, 602, 620

THEORETICAL PARTICLE PHYSICS AND FIELD THEORY

P. Forgács, A. Frenkel, Anna Hasenfratz, P. Hasenfratz, P. Hraskó, M. Huszár, J. Kuti, T. Margaritisz, Julia Nyiri, J. Polónyi, K. Szegő, K. Szlachányi, K. Tóth

During the last two years the focus of our group's attention in field theory was on Quantum Chromodynamics (QCD). QCD is the leading candidate to describe the theory of strong interactions.

The rather large scale work, which was carried out by several members of our group, applied the so-called lattice regularized version of QCD. This type of QCD, while preserving the basic principles and formalism of quantum field theory, makes it possible to adapt a number of fundamental results of statistical physics.

Among our results we would mention that concerning the physical scale on the lattice being related to the Λ-parameter of deep inelastic lepton-nucleon scattering. Interesting results have also been obtained by investigating string fluctuations. A special type of phase transition, called "roughening" in statistical physics, was found, which had previously been unknown in particle physics.

Considering strongly interacting hadrons and quarks as different phases of the same physical medium, a successful calculation was carried out in connection with the characteristics of the phase transition between nuclear and quark-gluon matters. An estimate was given for the critical temperature of quark liberation.

Our research in classical gauge theories resulted in a new, exact solution of the field equations in SU(2) gauge theory.

The major part of our phenomenological investigations was devoted to studying the bag model of hadrons. In the framework of the MIT bag model the spectroscopy of heavy particles was successfully elaborated.

In a work of more classical nature it was shown that the non-uniqueness, which can be observed in the extension of the high-energy models (such as parton model, multiperipheral model, etc.) to non-zero transverse momenta, can be related to some subgroups of the Poincaré group. The various possible extensions are correlated with the behaviour of the relevant functions (structure function, off-shell scattering amplitude, etc.) in essentially different asymptotic limits.

PUBLICATIONS: 18, 94, 119, 146, 147, 148, 149, 160, 260, 261, 311, 482, 483, 542, 543, 590, 654

EXPERIMENTAL PARTICLE PHYSICS: μN DEEP INELASTIC SCATTERING

G. Eszes, G. Jancsó, I. Mannó, E. Nagy. Cs. Postásy, P. Ribarits, J.D. Tóth, L. Urbán, Gy. Vesztergombi

The group is participating in two big international collaborations. Two members of the group have been working in the collaboration CERN-Dubna-Munich-Saclay (experiment NA4 at CERN), the others have been participating in the two experiments of the European Muon Collaboration (EMC, experiments NA2 and NA9 at CERN). Both collaborations are studying the μN deep inelastic scattering using the high energy muon beam of the CERN super proton synchrotron.

In the NA4 experiment the first part of the data collecting is finished, the collaboration is working on the off-line data analysis. Some preliminary results have been presented at international conferences on the nucleon structure functions and on the multimuon final states.

The data collecting is finished in the NA2 experiment, too; the EMC is working on the data analysis and on the installation of the new vertex detector system for the NA9 experiment. The EMC measured the nucleon structure function F_2 on different targets and at different muon energies. The data show a definite scaling violation *(Fig. 1)*. Results have been

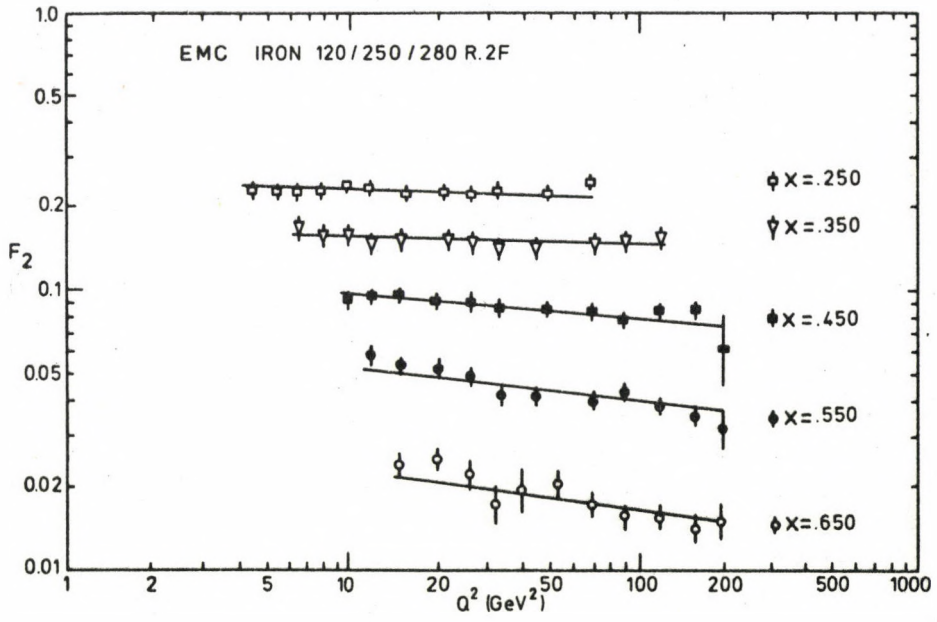

Fig. 1

Nucleon structure function (F_2) versus Q^2 (Q^2 = -1 × mass square of the virtual photon) for different values of scaling variable x. The lines are fits from the Quantum Chromodynamics

obtained on the multimuon events, on the J/Ψ production and on the single particle distributions of the produced hadrons.

The NA9 detector system contains a 2 m long streamer chamber together with electronic detectors, so the group is also working on the processing of the streamer chamber pictures. The main parts of the software chain necessary for the picture processing on the new automatic measuring system RIMA have been elaborated. The group have been working on the software for the semi-automatic measuring devices.

PUBLICATIONS: 2, 5, 6, 7, 8, 22, 23, 51, 56, 94, 111, 249, 252, 253, 375, 376, 377, 378, 379, 380, 381, 673

RISC-SPECTROMETER EXPERIMENT

E. Dénes, L. Diósi, T. Gémesy, D. Kiss, S. Krasznovszky, G. Pintér, J. Spitzer, I. Wagner

The RISC-spectrometer is a hybrid detector consisting of a 5 m long streamer chamber and the trigger system of different types of counter arrays.

The aim of the experiment is to investigate some rarely occurring strong interaction processes.

In 1978 the spectrometer was installed at the proton synchrotron of the Institute for High Energy Physics, Serpukhov, USSR.

At the site a permanent team of about nine Hungarian physicists and technicians has been taking part in the enlargement and improvement of the experimental equipment as well as writing programs to facilitate the data handling and film measurements.

In Budapest great effort has been made to design and construct a new automatic film measuring device, which meets the special requirements of the films of large streamer chambers. A great part of the software support of this device has been accomplished by the RISC team.

Off line data processing programs as well as utility programs have been coded and tested in the last two years.

Apart from this work, 7000 frames of film have been scanned to investigate the multiplicity distributions in hadron-proton and hadron-nucleus interactions.

STUDY OF ELEMENTARY PARTICLES IN A BUBBLE CHAMBER

T. Gémesy, Livia Jenik, S. Krasznovszky, G. Pintér

The investigations on hadron-nuclei and nucleus-nuclei interactions have been continued in the 2 m propane bubble chamber of the Joint Institute for Nuclear Research, Dubna, USSR.

The characteristics of multinucleon interactions of π^- mesons have been studied at p = 40 GeV/c with carbon nuclei. The main result obtained is that: in the central region the azimuthal correlations of $(\pi^+\pi^-)$ pairs are in good agreement with the additive quark model predictions for multinucleon interactions.

The inelastic cross-sections and multiplicities of negative pions produced in the collisions of p,d, ^{4}He and ^{12}C nuclei (with incident momenta of 4.2 GeV/c per nucleon) with Ta have been studied in the propane bubble chamber.

Average multiplicities and dispersion of multiplicity distributions of nucleus-nucleus and nucleon-nucleon collisions have been compared. It has been observed that the C-Ta point deviates from the empirical Wroblewski curve *(Fig. 2)*. It was found that the pion multiplicities are

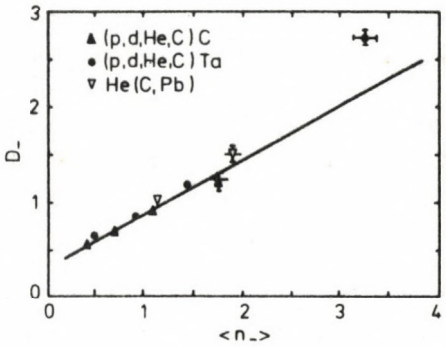

Fig. 2

Dependence of experimental dispersion values $D_- = \sqrt{\langle n_-^2\rangle - \langle n_-\rangle^2}$ *on average negative particle multiplicities* $\langle n_-\rangle$ *in pA and AA interactions. The straight line represents the empirical Wroblewski dependence for inelastic pp interactions*

proportional to the number of nucleons of the incident nucleus interacting with the target. Our results do not contradict the assumption that the nucleons from the incident nucleus interact independently with the target.

For C-Ta interactions the average radius of the pion emission volume has been determined by the interference method and it is (3.3 ± 0.6) fermi.

PUBLICATIONS: 16, 17, 130, 358, 370, 384, 477, 478

THEORETICAL STUDIES IN COSMIC RAY PHYSICS

G. Erdős, T.I. Gombosi, P. Király, J. Kóta, A.J. Somogyi*

Our theoretical works were focused on the problems of propagation of energetic charged particles in interplanetary and interstellar magnetic fields.

In the MeV energy region, particles propagating along magnetic field lines suffer pitch angle scattering due to small-scale magnetic irregularities. The connection between the pitch angle diffusion coefficient, $D_{\mu\mu}$, and the spectrum of the random component of the interplanetary magnetic field is not yet clear; an approximate relation is given by the Quasi Linear Theory (QLT). In an attempt to test the QLT we carried out, in cooperation with the Bartol Institute, Newark, Delaware, USA, a Monte-Carlo simulation in a magnetic field model constructed so as to give the same power spectrum as that given by the real interplanetary field. It has been found that, in contrast to the QLT, $D_{\mu\mu}$ has a finite value at perpendicular pitch angle. At the same time, however, QLT has been shown to give a surprisingly good estimate for the spatial diffusion coefficient.

Recent works have pointed out the importance of curvature and gradient drifts in interplanetary space and, as a consequence, the utmost necessity of a three-dimensional treatment of cosmic ray modulation in the 100 MeV - 10 GeV range, where particles are less tightly bound to the field lines. We ourselves deduced a three-dimensional force-field solution under some reasonable assumptions. We also called attention to the role the wavy structure of the interplanetary magnetic neutral sheet may be playing. Cosmic ray intensity at the earth turned out to decrease when the "wave-height" of the neutral sheet was increased. This may well account for the 11-year variation of cosmic ray intensity in inverse correlation with solar activity. We were also able to explain some of the differences between cosmic ray modulation in even and odd cycles, respectively.

The waviness of the interplanetary neutral sheet was shown to have important effects at higher energies (50-200 GeV), where particles become insensitive to the small-scale irregularities, but they still experience the large scale interplanetary field. By calculating energy losses along regular trajectories we predicted cosmic ray anisotropies and gradients. We were able to interpret the phase-shift of the daily intensity-waves observed to take place in 1969 in connection with the solar polarity reversal. The predicted gradients cannot be checked since no direct measure-

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* Theoretical Research Group of the Institute

ments are available far from the earth at high energy. Nevertheless, our results are in encouraging agreement with the general trends experimentally established at lower energies.

Galactic cosmic ray anisotropy was investigated in cooperation with scientists of the University of Durham, Durham, England. The 10^{11}-10^{14} eV range, where the bulk of the positive measurements clusters, was studied in great detail and arguments were brought forward supporting that anisotropy should change slowly and smoothly in this energy interval. We also made an attempt to arrange the experimental and theoretical results so far available into a coherent picture for the whole energy range 10^{11}-10^{20} eV.

In cooperation with the Bartol Institute, Newark, Delaware, USA, we studied the galactic propagation of cosmic rays in a dynamical halo model. By performing a numerical calculation we determined the mean age and grammage of cosmic rays in the galaxy allowing for an energy dependent diffusion coefficient.

PUBLICATIONS: 99, 100, 139, 187, 188, 189, 205, 206, 207, 208, 209, 210, 444, 471, 472, 592

CLASSICAL COSMIC RAY RESEARCH

G. Benkő, G. Erdős, K. Kecskeméty, J. Kóta, G. Neuprandt, A.J. Somogyi, Mária Tátrallyay, A. Varga

High energy cosmic rays (above ~10^{11} eV) lying beyond the possibility of direct space measurements are investigated by earth-based experiments. The underground muon telescopes, operated in the Institute since 1958, cover the lower part of this energy range (10^{11}-10^{12} eV) which is an intermediate region where the influence of the interplanetary magnetic field ceases. The deviation from the isotropy in the angular distribution of galactic cosmic rays is studied on the basis of the sidereal diurnal variation. By comparing our sidereal vectors obtained in the sectors of alternating interplanetary magnetic field in the period 1958-63 with those of a similar apparatus located at opposite geographical latitude we were able to separate the solar effects from the effects stemming from outer, galactic anisotropy *(Fig. 3)*.

On the basis of recent measurements by the underground telescopes we continued the analysis of abrupt cosmic ray intensity decreases (Forbush effects). The most significant events observed were on 15 February, 1 May, 2 June and 13 July, 1978. On 15 February the amplitude was 2.0 per cent which almost reached that of the huge August 1972 event.

The fast decrease and recovery leads to the conclusion that the event resulted from a magnetic structure of a forward-reverse shock wave system. The comparison with other underground observations indicates a power-law rigidity dependence of the amplitude $A(P) \propto P^{-\gamma}$ with $\gamma = 1.2 \pm 0.2$ *(Fig. 4)*.

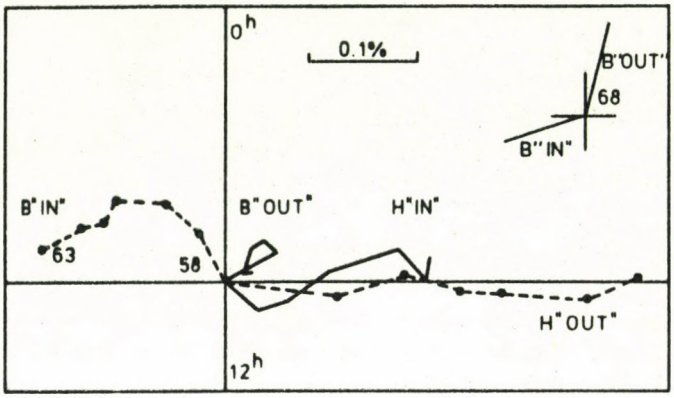

Fig. 3

Harmonic dial of sidereal daily variation observed in Budapest (B) and Hobart, Australia (H) in the sectors with interplanetary magnetic field pointing outwards and inwards to the sun

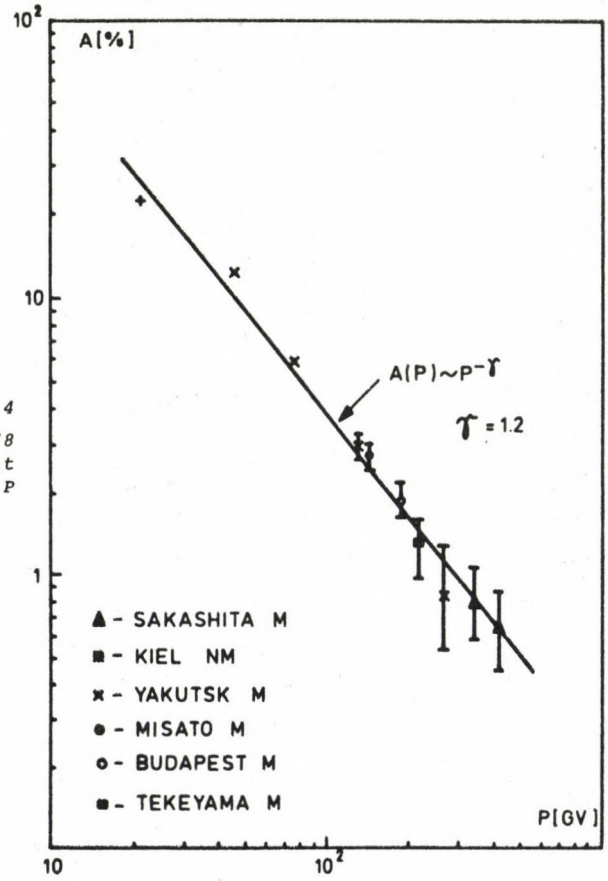

Fig. 4

Amplitude of 15 February, 1978 Forbush event observed at various rigidities, P

In order to improve the stability of our telescopes and to avoid frequent replacements of the Geiger-Müller counters we decided to substitute them by proportional counters. For this purpose one telescope was constructed and set up at the surface level. Having performed efficiency measurements on multi-wire proportional chambers and on proportional tubes of cylindrical shape we preferred to use the latter type with continuous gas rinsing. The surface telescope has a semi-cubical geometry (as sketched in *Fig. 5*), built from 128 aluminium tubes assembled in four layers (A, B, C and D) of four blocks each (giving a total sensitive area of 1.88 m^2). Between layers B and C absorber material is placed consisting of 2x75 mm lead and 2x10 mm iron. Each block of 8 counters has a common amplifier and mixer unit. The efficiency of the tubes reaches (99.5 ± 0.3) per cent at the high voltage plateau (width: 150 V). The gas (a mixture of 70 per cent argon and 30 per cent CO_2) flows through the system at a rate of 6 l/hour. Fourfold coincidences are counted and analysed by a CAMAC unit to give counting rates from vertical and inclined (east and west at 32^o zenith angle) directions. With a coincidence of 2.5×10^{-6} s time resolution we obtain the counting rates: 4.30×10^5 c/h (vertical) and 1.53×10^4 c/h (inclined). The background 3+1 coincidences give a contribution of $C_{3+1}/C_4 \approx 6 \times 10^{-4}$. The surface telescope works in an energy range about ten times lower than the underground ones which enables us to extend our study of solar modulation effects to lower rigidities.

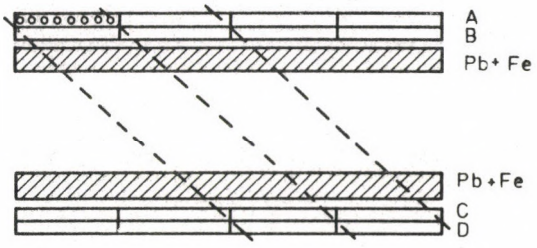

Fig. 5

Geometrical scheme of proportional counter telescope (dashed lines indicate inclined telescopes)

The full scale measurement begun in 1978 has been continued with the extensive air shower array located in the Tien Shan mountains near Alma Ata in the Soviet Union in cooperation with the Lebedev Physical Institute, Moscow. The experiment was designed to detect the anisotropy of galactic cosmic radiation at the energy of ~10^{14} eV.

PUBLICATIONS: 43, 45, 46

SPACE PHYSICS

T.I. Gombosi, G. Huba, K. Kecskeméty, J. Kóta, Erzsébet Merényi, A.J. Somogyi, Annamária Szentgáli-Páldi, Mária Tátrallyay, A. Varga

In 1979-80 we continued the data reduction of the Prognoz satellites. We completed processing the Prognoz-5 and about 75% of the Prognoz-6 data. At the same time, further analyses and interpretations of Prognoz-3, Prognoz-4, Prognoz-5 and Prognoz-6 were carried out in collaboration with scientists of the Nuclear Research Institute of the Moscow State University and the Space Research Institute, Moscow, USSR.

Together with our Soviet colleagues we continued the study of the vicinities of Mars and Venus as well as of the interplanetary medium on the basis of Venera-9, Venera-10, Venera-11, Venera-12, Mars-4, Mars-5, Mars-6 and Mars-7 data. In collaboration with scientists of the University of Michigan, Ann Arbor, Michigan, USA, we carried out theoretical studies on solar wind interaction with Venus.

On the basis of a statistical study of ESP (energetic storm particle) events we established new experimental correlations between the parameters of the shock wave, the ambient interplanetary medium and energetic particles. The best correlation was obtained between the integrated energy flux of 1-80 MeV protons and the jump of the total pressure, i.e. the sum of magnetic and thermal pressure.

We analysed the time-intensity profiles of 85 KeV - 500 MeV protons on the basis of Prognoz-6 observations during a particle event following the W40° solar flare on 22 November 1977. The interplanetary medium was

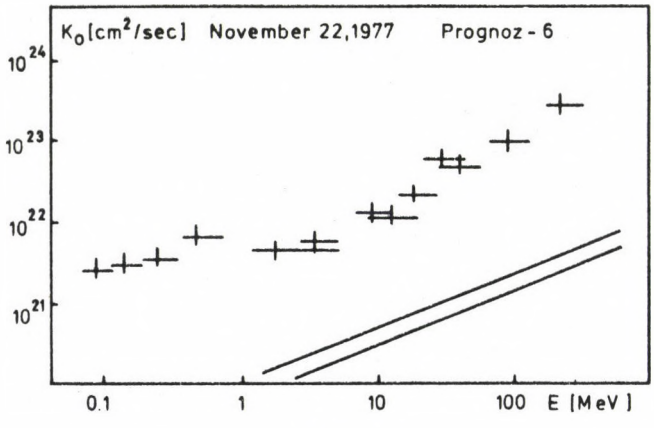

Fig. 6

Comparison of experimental and theoretical values of K_0 vs. particle energy (E). Solid lines represent predictions of the quasilinear theory based on observed IMF power spectra in various periods of solar activity (Hedgecock, 1975)

quiet during this event, as the flare occurred after a solar quiet period and was not followed by other ones for several days. We were able to fit well the observed intensities in terms of a model containing coronal propagation with an energy-dependent diffusion coefficient (K_o) and interplanetary diffusion with a coefficient varying with the heliocentric distance. *Figure 6* shows the energy dependence of this diffusion coefficient at the orbit of the earth. The solid curves represent the prediction of the quasilinear theory, which is obviously inconsistent with our results.

Inspired by this inconsistency we carried out a detailed numerical study and proved that the simple diffusion picture for solar particle transport can give quite misleading results. Although the intensity-time profiles "look" diffusive, for small scattering mean free paths ($\lambda \lesssim 0.1$ a.u.) the fitted profiles significantly over-estimate λ. This may explain the discrepancy of the λ values obtained experimentally from the theoretical ones. *Figure 7* shows the connection between the radial mean free path deduced from observed profiles and the λ values obtained from quasilinear theory.

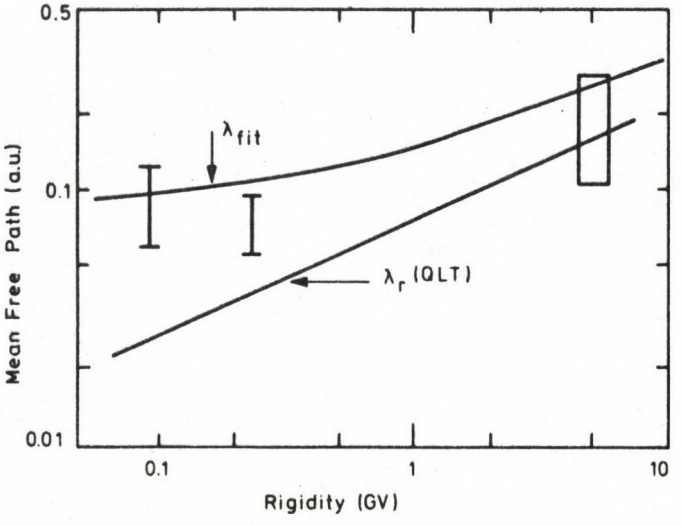

Fig. 7

Connection between mean free path (λ) and rigidity. One of the solid lines (λ_r(QLT)) gives the actual mean free path used in the calculations based on QLT, the other (λ_{fit}) represents the mean free path obtained by fitting the actual calculated profiles to a spherically-symmetric spatial diffusion model. The points are the experimental values of Zwickl and Webber and the box is our rough estimate based on a few neutron-monitor events

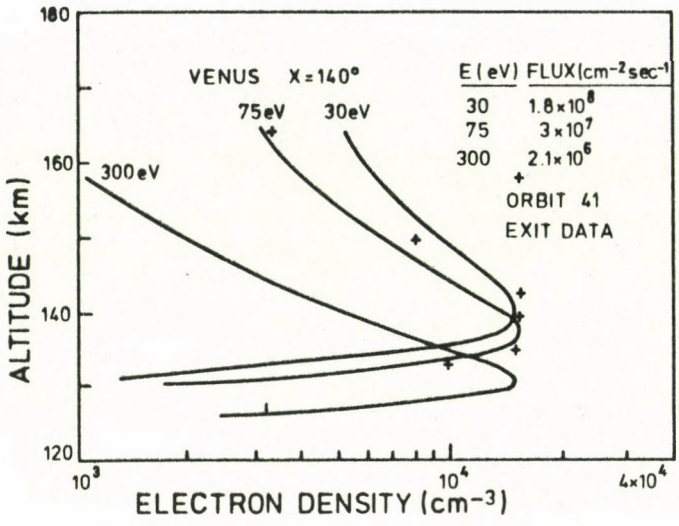

Fig. 8

Computed electron density profiles resulting from the precipitation of 30, 75, and 300 eV electrons into the nightside atmosphere modelled after Pioneer Venus in situ measurements. The crosses are points from the electron density profile derived from orbit 41 exit radio occultation

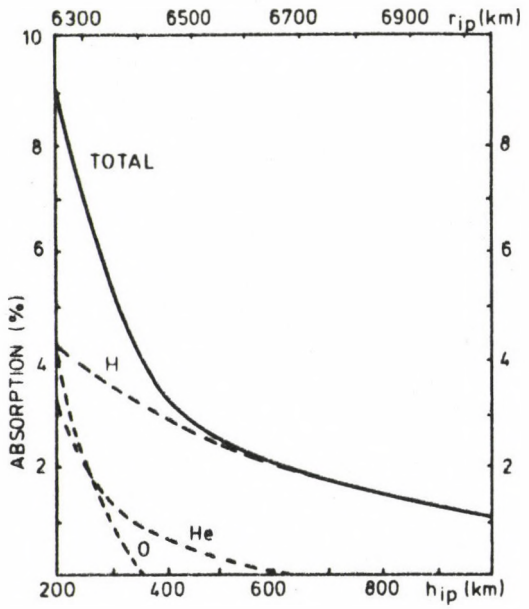

Fig. 9

Solid wind absorption by the dayside neutral atmosphere as a function of ionopause altitude, h_{ip}. (r_{ip} refers to radial distance from the centre of the planet). The solid curve represents the total absorption, the dashed lines represent the absorption by H, He and O atoms

Using a very simple model we showed how diffusion of solar wind ions and electrons into the wake of Venus can result: in lowered nightside ionopause heights - due to the pressure of the diffusing ions; in significant fluxes of low energy electrons and/or protons into the nightside ionosphere. Using a nightside neutral density model consistent with Pioneer Venus in situ measurements, we calculated electron density profiles resulting from the precipitation of 30, 75, and 300 eV monoenergetic electrons *(Fig. 8)*. The particle fluxes used were adjusted for each energy to give a peak electron density of 1.5×10^4 cm^{-3}, in agreement with the typical measured value at $\chi = 140^{\circ}$. It is clear that 300 eV electrons penetrate too deeply, producing a maximum at about 130 rather than 140 km. However, *Fig. 8* indicates that fluxes of about 10^8 cm^{-2} sec^{-1} of electrons with energies less than about 100 eV are capable of producing electron density profiles that agree with the observations.

The extent to which the shocked solar wind interacts with and is "absorbed" by the planet is still a central question for the planet Venus. In a recent work, we have pointed out that the density of He, O and thermal H atoms is not negligible at altitudes where the shocked solar wind flows around the dayside of Venus, consequently a solar wind particle has a significant probability of participating in a charge transfer interaction with a neutral atom, which produces a new fast neutral hydrogen atom and a slow heavy ion. The resulting absorption is shown in *Fig. 9*. Inspection of *Fig. 9* shows that for an ionopause altitude of 250-1000 km, values for the total amount of the solar wind removed by charge exchange is between 1 and 7%.

PUBLICATIONS: 44, 88, 134, 135, 136, 137, 138, 140, 196, 213, 214, 423, 424, 470, 541, 577

NUCLEAR AND PLASMA PHYSICS

THEORETICAL NUCLEAR PHYSICS

Gy. Bencze, I. Borbély, L. Csernai, P. Doleschall, T. Dolinszky, Gy. Kluge, I. Lovas, B. Lukács, J. Polónyi, J. Révai, J. Zimányi

In the framework of a molecular three-body model, based on the exact eigenfunctions of the two-centre problem introduced earlier, we have performed detailed calculations on the structure of the ^{9}Be nucleus. Supposing the validity of the α+α+n three-body picture we have been able to evaluate the energies and wave functions of the ground- and low lying excited states of ^{9}Be. The results of the calculations are in good agreement with the experimental values.

The three-nucleon system is sensitive to the on- and off-shell behaviour of the nucleon-nucleon (N-N) interaction. Therefore, a comparison of the three-nucleon Faddeev calculations and the corresponding experimental data might give some new information about the N-N interaction. During the period 1979-80, neutron-deuteron elastic scattering and break-up calculations were performed. The N-N interactions, based on present phase shift analyses, did not produce satisfactory agreement with the experimental vector polarizations. The possible reason for the disagreement could be our poor knowledge of the low energy N-N phase shifts. Further three-nucleon calculations may help to obtain more accurate low energy N-N phase shifts.

The general analytic properties of polarizations and the possibilities of an empirical continuation to the transfer pole were studied. By extrapolating the $d(\vec{d}, p)t$ tensor polarization data, the D/S state ratio of the deuteron and triton was determined.

The new developments in the exact formulations of N-particle scattering theory have not as yet found applications in nuclear reaction theory. The problems due to the identity of particles as well as the Coulomb repulsion between protons have been solved either exactly or an approximate procedure has been suggested. Other conceptual problems, e.g. non-orthogonality effects, which appear in conventional formulations, are being investigated and a new N-particle approach to the treatment of nuclear reactions is being developed.

The high-energy A(p,p'd)B reaction was investigated in the quasi-free scattering region. The QFS cross section is expressed as an integral of the product of the two-nucleon spectral function of the target nucleus and the scattering matrix element of the three-nucleon system. It is pointed out that the three-nucleon scattering matrix elements can be related to the amplitude of the p+d→p+p+n break-up reaction with the help of time reversal invariance. The cross section of the A(p,p'd)B reaction can thus be expressed in terms of the proton-deuteron break-up cross section taken at the two-nucleon final-state interaction peak.

The process when a light projectile is colliding almost centrally with a heavy target has been described by a one dimensional hydrodynamical model as well as by a phenomenological one.

The dynamics of heavy-ion collision has been described for a one dimensional hydrodynamical model. The density and temperature increase and the width of the evolving shock front are evaluated in the initial phase. The differential cross section and the rapidity spectrum of the nucleons emitted from the explosion, caused both by the flow and by the thermal energy, have been calculated. A description of the phase transitions occurring in shock waves has been formulated and discussed.

Experimentally observable consequences of a possible "Bose-Einstein condensation" of pions in energetic heavy ion collisions have been demonstrated. An excess of low energy pions observed in recent experiments does in fact seem to indicate a Bose-Einstein condensation-like phenomenon.

Proton and pion spectra from relativistic heavy ion collisions are calculated in the framework of a hadrochemical model. An explanation for the striking absence of the delta decay pion peak in the observed pion spectra is suggested.

The asymptotic exactness of the WKB formula for the high energy phase shift, proven previously for inverse power potentials, has been shown in terms of a new phase approach to hold for the general class of strongly singular interactions. Within the framework of the standard phase method, a new calculation scheme has been developed that reduces, in comparison with the integral equation approach, the number of integrations needed for obtaining the half-off-shell matrix elements in the nonlocal case.

PUBLICATIONS: 31, 38, 39, 40, 41, 42, 50, 58, 59, 71, 72, 73, 74, 75, 95, 114, 129, 142, 225, 250, 286, 287, 288, 352, 353, 354, 355, 356

ISOBARIC ANALOGUE RESONANCES

Ilona Fodor-Lovas, J. Sziklai

$2d_{5/2}$ IAR fragments have been found in ^{57}Co corresponding to the E_x = 2.506 MeV level in the ^{57}Fe parent nucleus. The IAR fragments were located through the $^{56}Fe(p,\gamma)^{57}Co$ reaction with the aid of differential type excitation curves. On the basis of these curves *(Fig. 1)* and the analysis of angular distributions measured at each resonance four fragments were found in the energy region examined. Our earlier experiments gave some hints on the likelihood of there being more fragments outside this energy region too. Study of all possible fragments in a much wider energy range and the full and detailed analysis of this fragmented $2d_{5/2}$ IAR are in progress.

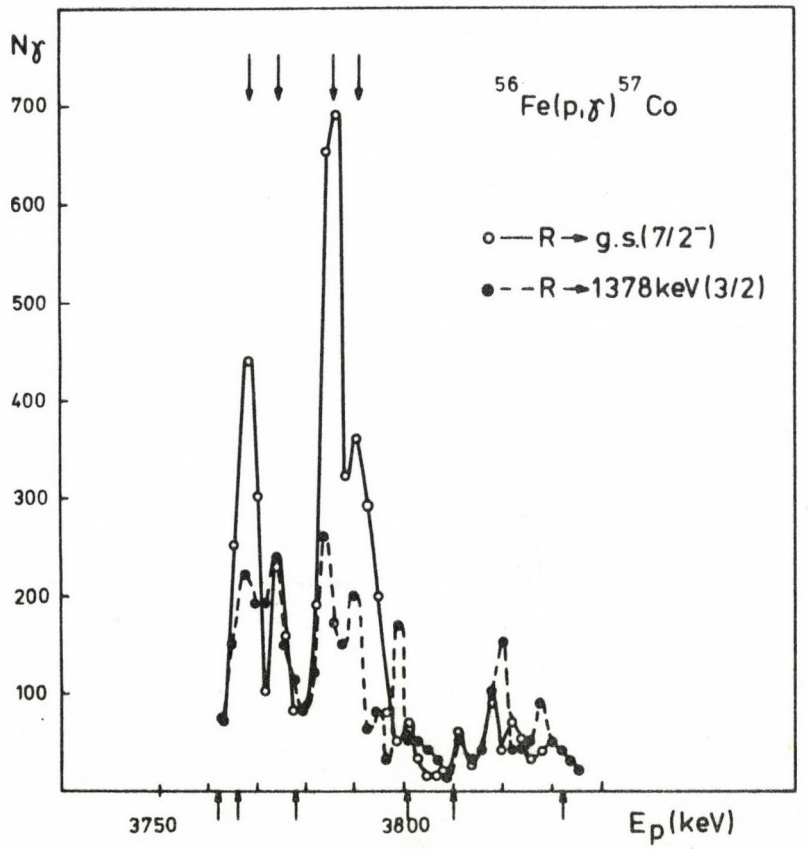

Fig. 1

Differential type excitation curves for two primary transitions in the $^{56}Fe(p,\gamma)^{57}Co$ reaction. Arrows show the positions of the already identified $2d_{5/2}$ IAR fragments

The fragmentation of the $2d_{5/2}$ IAR excited in the $^{58}Ni(p,p_o)^{58}Ni$ reaction was also studied. The corresponding parent state was found at E_x = 4.504 MeV(C^2S = 0.234) in the $^{58}Ni(d,p)^{59}Ni$ reaction. Taking into account the Coulomb energy difference the IAR was expected to appear at $E_p \cong$ 4.8 MeV bombarding proton energy. The fragmentation of this IAR seemed to be very strong. The $2d_{5/2}$ IAR fragments were spread over a region of ~1 MeV *(Fig. 2)*. However, the final analysis of this IAR, i.e. fitting the theoretical strength function to the strength distribution found experimentally, has been affected by the fact that in this relatively wide analogue range could lie other $2d_{5/2}$ analogue states corresponding to parent states within ~0.5 MeV around the strongest parent state E_x = 4.504 MeV.

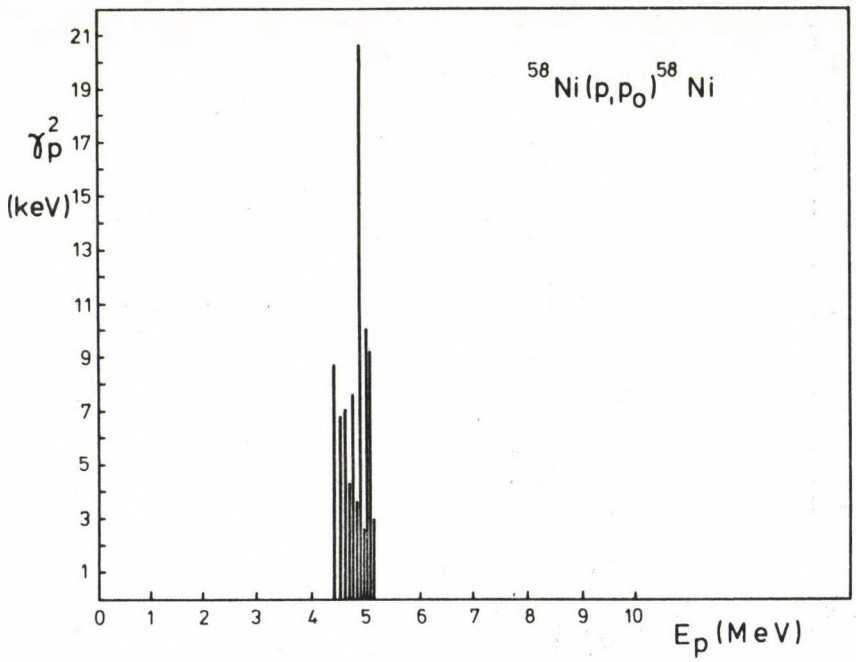

Fig. 2

Distribution of the reduced partial width squares deduced from the $^{58}Ni(p,p_o)^{58}Ni$ experiment

These activities were carried out in cooperation with researchers of the Zentralinstitut für Kernforschung, Rossendorf, GDR.

PUBLICATIONS: 112, 113, 172, 173, 174, 175, 176, 177, 465

COUPLED-CHANNEL EFFECTS IN DIRECT REACTIONS

Gabriella Pálla

Two-neutron transfer reactions on even-even Sm isotopes which are known to have strong collective nature have been investigated. Some of their states, namely the low-lying collective states, have been found to have rather flat angular distributions not characteristic of any particular ℓ-transfer and they are left without any satisfactory explanation. So far as the reaction mechanism is concerned difficulties may arise particularly when the final nuclear states - even at low excitation - have a parentage that is based rather on an excited state of the parent nucleus than on its ground state. The transition can then proceed through two-step processes involving inelastic scattering and two-neutron transfer. In this case the one-channel optical model used in constructing the scattering state wave functions for the DWBA calculation breaks down and the coupled channels Born approximation (CCBA) including inelastic scattering has to be used.

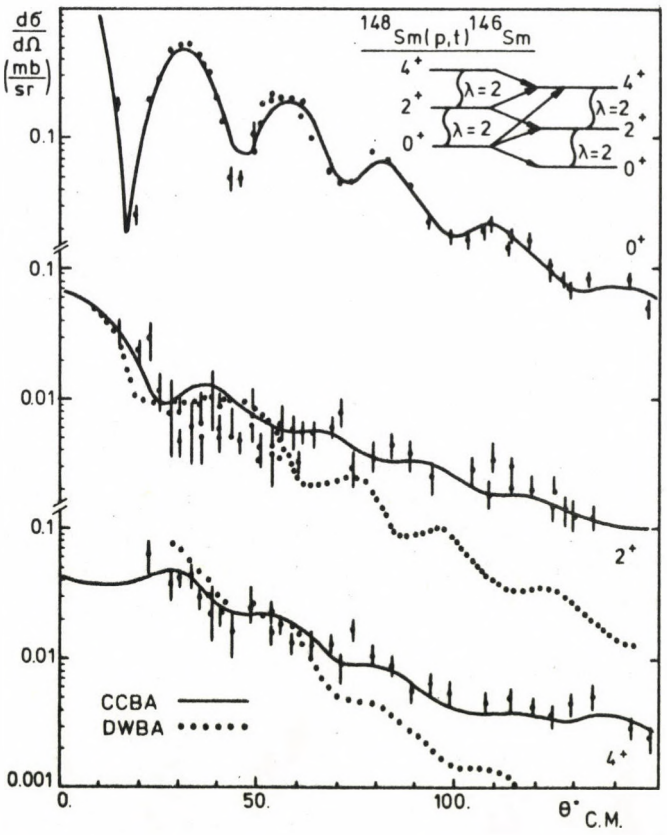

Fig. 3

Differential cross sections of $^{148}Sm(p,t)^{146}Sm$ reaction leading to the low-lying vibrational collective states. The solid lines show the results of the coupled channels Born approximation, the dotted lines are data of the distorted wave Born approximation

Zero-range channels Born approximation has been used to explain the two-neutron transfer reactions ^{148,150,154}Sm(p,t) leading to the low-lying excited states of final nuclei. An example of the results is shown in *Fig. 3*. There are serious deficiencies in the ability of the single-step calculations to describe adequately the shapes and magnitudes of the angular distributions. For both the vibrational and permanently deformed Sm nuclei excellent agreement has been found assuming the multi-step reaction mechanism including inelastic excitation of the collective low-lying states in both the target and final nuclei. The coupled channels analysis has resulted in new spectroscopic information which could not be provided by the usual simple DWBA method.

PUBLICATIONS: 266, 267, 268, 401, 596, 681

NUCLEAR FISSION STUDIES

J. Kecskeméti, Gy. Kluge, A. Lajtai

The prompt neutron spectra for the energy range 10 keV to 3 MeV from fission of U-233 and Pu-239 by thermal neutrons have been measured by the time-of-flight method using NE-912 and NE-913 lithium glass as a neutron detector. The fission fragments were detected by gas scintillation counter. In order to determine neutron detector efficiency the prompt neutron spectrum from the spontaneous fission of Cf-252 was measured under the same experimental conditions. The experimental results show that the energy spectra of prompt fission neutrons from thermal neutron fission of U-233 and Pu-239 can be described by distributions of Maxwellian type with parameters T = 1.32 and T = 1.38, respectively.

Calculations have been performed for fission reactions ^{233}U(p,f) and ^{238}U(p,f) to determine the division of excitation energy between the fragments, i.e. the number of prompt fission neutrons, as a function of the total excitation energy. With the disappearing shell effects dominating in the level densities at low excitations a transition to neutron number distribution corresponding to the liquid drop limit is obtained at higher excitations.

PUBLICATION: 201

QUASI-FREE INTERACTION OF PROTONS OF INTERMEDIATE ENERGY

J. Erő, Z. Fodor, P. Koncz, Z. Seres

The investigation of the quasi-free interaction of 670 MeV protons with nucleon pairs has been continued in collaboration with the Laboratory of Nuclear Problems of the Joint Institute for Nuclear Research, Dubna, USSR.

The evaluation of the experimental data on reactions of (p,xd) type has been completed and inclusive experiments were performed to investigate over a wide energy range of protons the energy spectra scattered from light elements at backward angles.

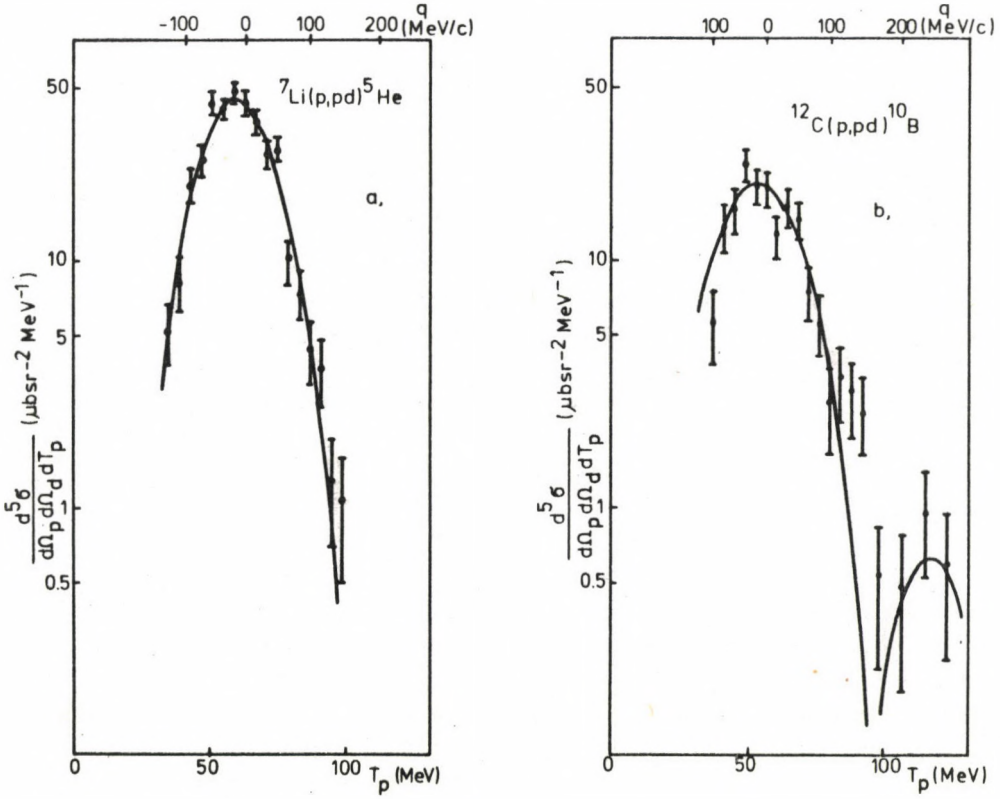

Fig. 4

Energy sharing distributions of reactions ^{7}Li, ^{12}C(p,pd) for ground and low excited states. Upper scale shows the momentum of the relative motion. Full lines represent Monte Carlo calculations using momentum distributions:

a) Gaussian type of width q_o = 75 MeV/c

b) 2S harmonic oscillator type with oscillator parameter q_o = 155 MeV/c using strong cut-off radius R_c = 2.6 fm

By investigating the (p,pd) reaction on ^{7}Li and ^{12}C nuclei by kinematically complete measurements, it was found that these processes proceed by quasi-free scattering mechanism and excite with large probability the low lying levels of the residual nuclei. The cross sections of these transitions are in fairly good agreement with calculations, based on shell-model wave functions taking into account the absorption of the particles *(Fig. 4)*. With highly excited states, quasi-free scattering in the s-shell of the nuclei plays an important role.

In the inclusive proton spectrum emerging from the interaction with free deuterons at $\Theta = 150^{o}$, besides the elastic peak there was observed a wide continuum which cannot be described by simple theoretical models and it suggests the participation of more complicated processes *(Fig. 5)*.

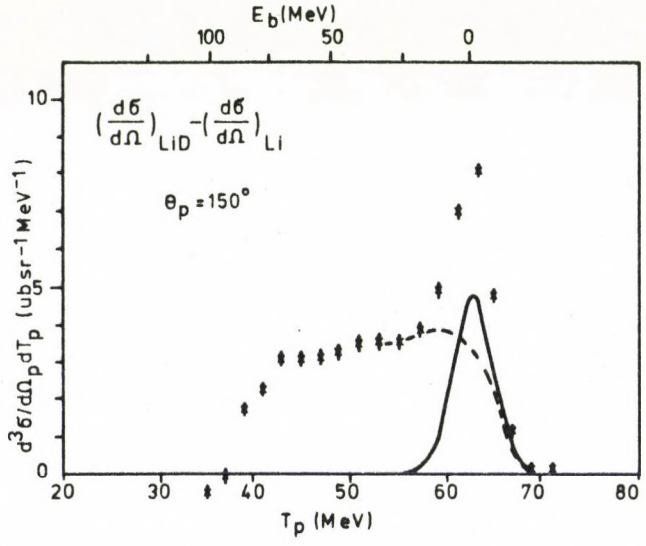

Fig. 5

Inclusive proton spectrum at $\Theta_p = 150^{o}$ obtained as the difference between the cross sections measured with LiD and Li targets. The full line represents the elastic cross section with experimental resolution, the broken line is the inelastic part of the cross section. E_b gives the internal energy of the recoiled p-n system

The inclusive cross section on ^{6}Li, ^{7}Li, ^{12}C and ^{63}Cu nuclei exceeds several times the free deuteron cross section and the energy distribution of the protons is rather smooth, without any marked structure. This leads to the conclusion that interactions with nucleon groups inside the nuclei contribute only slightly to the inclusive process.

PUBLICATIONS: 3, 4, 200, 343, 363, 529

MÖSSBAUER STUDIES ON CONDENSED SYSTEMS

Judit Balogh, I. Dézsi, Gy. Forgács, D. Horváth, E. Kótai, G. Mezey, B. Molnár, D.L. Nagy, I. Szücs, B. Vajna
*Visiting research worker: J. Mulhem**

As a continuation of our previous lattice location studies of Co implanted in Si similar studies on diffused samples have been performed. The Mössbauer spectra of ^{57}Co atoms diffused into Si depend very much on the conditions of sample preparation (annealing time, temperature, quality of the vacuum, etc.). The spectrum of the sample annealed for 6 hours at 1420 K is an asymmetric doublet. When a magnetic field of 5 T at 4.2 K was applied it could be shown that the spectrum consisted of a single line (I.S. = 0.03 mm/s) and a quadrupole doublet (I.S. = 0.36 mm/s; Q.S. = 0.55 mm/s).

To compare the above spectra with those of some intermetallic Co-Si phases the ^{57}Co emission spectra of CoSi, $CoSi_2$ and $CoSi_3$ have been measured. It was found that the spectra of $CoSi_2$ and $CoSi_3$ resemble very much the spectra of ^{57}CoSi (1420 K, 6 hours) in view of which the formation of the nuclei of such intermetallic phases seems to be very probable in this case.

On the other hand, when the annealing was performed at 1270 K for 1 hour a narrow single-line spectrum was observed (I.S. = 0.06 mm/s). Channelling studies show that under such conditions about 80% of the Co atoms occupy substitutional sites in the Si lattice with a surface concentration of 8.1×10^{21} atom/cm^3, a value much above the solid solubility limit. It seems to be very probable that the CoO and SiO_2 layers on the Co/Si interface play an important role in the above process.

The crystallization of $Fe_{84}B_{16-x}C_x$ ($0 \leq x \leq 10$) glassy alloys has been investigated in cooperation with members of the Institute for Solid State Research and the Eötvös Loránd University, Budapest. Crystallization processes were followed by differential scanning calorimetry, the appearing phases were identified by Mössbauer spectroscopy and transmission electron microscopy. Crystallization for $x = 0$ and $x > 6$ takes place in two steps; for $2 \leq x \leq 6$, three steps can be observed. The amount of crystalline α-Fe precipitated in the first step strongly increases from $Fe_{84}B_{16}$ to $Fe_{84}B_{14}C_2$, but at higher C content it remains practically constant.

The crystalline structure of the phase formed in the second step depends upon the C content. At $x = 0$ the second step is tetragonal Fe_3B precipitation, whereas for $x = 8$ and 10 orthorhombic $Fe_3(B,C)$ is formed.

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* Tichren University, Latakia, Syria

Traces of the tetragonal $Fe_3(B,C)$ phase can be detected at x = 2 and 4. It is thought that the complexity of crystallization in the range $2 \leq x \leq 6$ is due to μm-scale composition inhomogeneities in the form of separate carbon and boron rich regions.

The study of the local symmetry of Fe^{2+} ions in frozen aqueous solutions of $Fe(ClO_4)_2$ was continued. The spectra measured at 4.2 K in applied magnetic fields up to 5 T could be described with reasonable accuracy in terms of a ligand field model. In this model the $(H_2O)_6$ octahedrons around the Fe^{2+} ions are trigonally distorted (probably due to the static Jahn-Teller effect). The trigonal splitting δ of the T_{2g} ground state of the Fe^{2+} ion seems to have a broad distribution ($\langle\delta\rangle \approx 700\ cm^{-1}$; FWHM (δ) ≈ 600 cm^{-1}) as a consequence of the glassy environment of the hexaquo complex.

The after-effects of the electron capture of radioactive ^{57}Co nuclei have been studied around the phase transformation temperatures of ^{57}Co-labelled $Fe(H_2O)_6(ClO_4)_2$ and $Fe(H_2O)_6(BF_4)_2$. The emission spectra show the presence both of Fe^{2+} and of Fe^{3+} ions. There is no significant difference between the transition temperatures measured in absorption and emission spectroscopy. On the other hand, the value of quadrupole splitting of Fe^{2+} ions in the emission spectra is about 10% less than those in the absorption spectra. This effect cannot be explained in terms of local heating nor by a size-effect model; it is thought that it might be a consequence of valence state relaxation.

PUBLICATIONS: 66, 89, 90, 91, 92, 156, 157, 158, 169, 215, 436, 438, 537, 581

POSITRON ANNIHILATION STUDIES

A. Balogh, I. Dézsi, Zs. Kajcsos, B. Molnár
*Visiting research worker: Khalid Al Ani**

Extensive investigations have been performed in order to study the electronic structure of two-component alloys in dependence of the alloying concentration. The positron annihilation parameters evaluated from measurements of positron lifetime and the 2γ-angular correlation of the annihilation quanta for Cu-Zn, Al-Mn, Fe-B alloys exhibit substantial changes only for alloys of higher (some %) alloying compositions compared with the values of the pure crystalline metals.

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* Nuclear Research Institute, Baghdad, Iraq

Because it has been well demonstrated from experiments on pure metals that positron annihilation is a powerful tool for studying the solid state in general, it has recently been applied to the study of amorphous metallic alloys. Positron lifetime and Doppler-effect measurements have been carried out on amorphous and recrystallized $Fe_{80}B_{20}$, $Fe_{78}Mo_2B_{20}$, $Fe_{32}Ni_{36}Cr_{14}P_{12}B_6$, $Fe_{40}Ni_{40}B_{16}P_4$, $Fe_{40}Ni_{40}P_{14}B_6$ samples. It was found that the electronic structure of the amorphous phase cannot be well approximated by models applied for periodic structure, furthermore the "positron-trapping" measured both in the amorphous and crystalline phases indicates the presence of "free volume" in both phases. These measurements were performed in cooperation with G. Brauer of the Zentralinstitut für Kernforschung, Rossendorf, GDR.

The processes of positronium quenching and inhibition in the liquid and glassy solid phases of the water-glycerol system have been investigated by means of inorganic quenching, inhibitor and neutral chemicals ($Fe/ClO_4/_2$, $Mg/ClO_4/_2$, $HClO_4$, $NaClO_4$) in different concentrations. On the basis of positron lifetime measurements performed in a broad temperature range it has been concluded that above processes are diffusion-controlled. This result seems to be indirect evidence of the so-called "spur-model".

PUBLICATIONS: 60, 61, 81, 89, 171, 292, 437, 513, 514, 515

NON-LINEAR PHENOMENA IN PLASMA

A. Ág, Gy. Páris

Non-linear transport phenomena and MHD equilibria have been investigated. These can be described by a system of differential equations of first order where the non-linearity is of second power, the conduction coefficients are given functions or constants and the spatial dependence is of second order. The unknown quantities may be the plasma density, temperature, magnetic field components, etc.

The following special cases have been studied:

1. If the spatial derivatives are absent the problem is a coupled system of equations of the non-linear wave-wave interaction. Wave coupling coefficients have been determined for a given magnetic field in a turbulent plasma. On the other hand we have investigated the time dependence of the three variables with the purpose of clarifying the appearance of the strange attractor.

2. The coupled oscillator system of Hénon and Heiles. With the help of the energy integral the phase space of 4 dimensions is reduced to one of 3. Numerical analysis has shown that the closed curves representing the regular regions exhibit hitherto unknown relationships and the existence of previously unrecognized regular islands.

3. In an equation of diffusion type with a dependence $D \sim \rho^{\sigma}$ (ρ is the plasma density, $\sigma > -1$) self similar solutions are produced; a self similar solution is produced for the singular case $\sigma = -1$ too.

4. A Padé approximation of the plasma dispersion function for the limiting cases and applications for plasma physics and electron optics have been given.

5. The equilibrium equation for the heat transfer and, for checking purposes, for the Astron magnetic configuration was investigated. We have demonstrated that if we formulate the equilibrium equation as a variation problem, then using the Ritz method, it is possible to determine where no solution exists, and if one exists where it is unique; it is also possible to determine where the bifurcations are and what are the characteristics of the different solutions.

6. Non-linear diffusion of the magnetic field in plasma was studied also. This problem is partially solved for the spheromak configuration. Here the non-linear time dependence of the externally excited plasma sphere is investigated. Physically, the non-linearity is reduced to the Hall-current approximation which is, by constant conductivity, the simplest hydrodynamic effect. If the Hall constant is small the non-linearity can be treated as a correction and it produces a slow diffusion-like time dependence, so the most important coefficients have been calculated.

PUBLICATION: 270

DIFFUSION OF ARGON IONS IN THE T-10 TOKAMAK

G. Hordósy, B. Kardon, A. Montvai, I. Szentpétery, M. Tegze

The aim of the investigation was the determination of the radial transport velocity of the impurities in plasma. For this purpose the behaviour of Ar^{+16} and Ar^{+17} was investigated in hot plasma by the method of X-ray diagnostics. In the experiments an accurately determined amount of argon was injected for 5 to 30 ms during steady state discharge. The amount of argon was small enough to have no effects on the plasma parameters, but it was sufficient for following the presence of argon ions.

The radial distribution of the electron temperature was determined by using a Si(Li) semiconductor detector *(Fig. 6)*. The radial transport velocity of argon ions was measured by the ls-2p transition in Ar^{+16} and by recombination radiation of Ar^{+17}. The results of measurements are shown in *Fig. 7*. It can be seen that both the intensity of transition ls-2p and the recombination radiation exhibit a maximum in the vicinity of the radius of r = 12 cm near to the q = 1 surface. This effect was also observed on the characteristic X-ray lines of Cr and Fe ions.

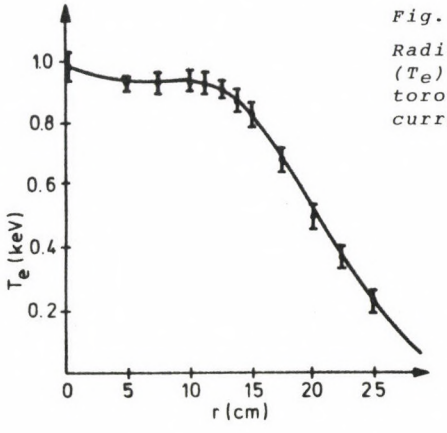

Fig. 6

Radial dependence of electron temperature (T_e) for the discharge with argon. The toroidal magnetic field and the plasma current were 16 kG and 230 kA, respectively

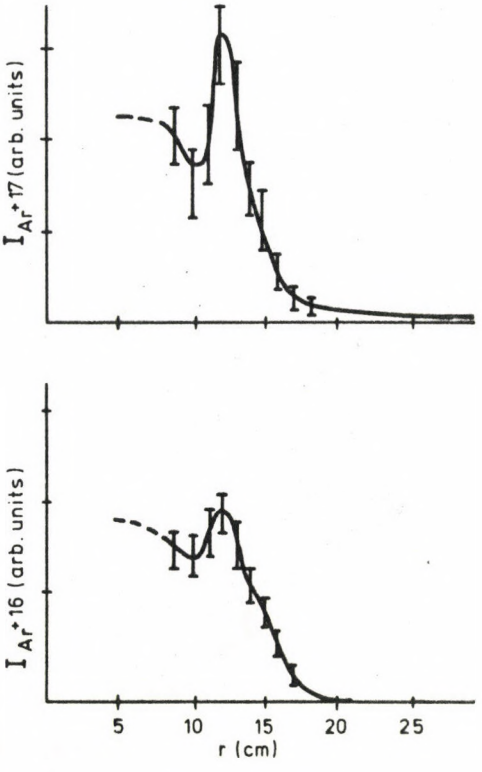

Fig. 7

Profile of the intensities of recombination radiation of Ar^{+17} and 1s-2p transition in Ar^{+16}

From the experimental results, with the help of the diffusion equation, the radial transport velocity of argon ions was determined and found to be $\simeq 4\text{-}5 \cdot 10^2$ cm/s.

PUBLICATIONS: 155, 181, 347, 415

STUDY OF PLASMA CHARACTERISTICS IN THE MT-1 TOKAMAK

G. Bürger, Gy. Hrehuss, P. Kostka, Z. Mészáros, I. Szentpétery, L. Vályi

After putting into operation the MT-1 tokamak the basic characteristics of its plasma have been studied. In *Fig. 8* the logarithm of the inverse MHD activity ($\tilde{B}_\varphi/B_\varphi$) is shown as a function of the gas-pressure (p) and plasma current (I_p) at fixed toroidal induction (B_z = 1 T). The surface characterizes the stable operation regimes of the tokamak and is bordered by the runaway-limit at the low-pressure side and by the high-current/pressure disruption edges, respectively, of the surface. Clearly shown are the magnetoacoustic resonances (see the minima in *Fig. 8*) corresponding to the different rational values $\frac{m}{n}$ of the safety factor q at the limiter. The poloidal mode-numbers m have been checked by the usual phase-correlation method making use of a set of poloidally distributed magnetic probes. The resonances correspond to surface-waves of strongly non-linear nature as is suggested by *Fig. 13*. In this figure the period T of the oscillations is plotted against the amplitude ξ_o (or $\tilde{B}_\varphi/B_\varphi$) in log-log scale. The calculated curves correspond to oscillations in different higher-order anharmonic potentials as deduced from a simplified non-linear MHD theory.

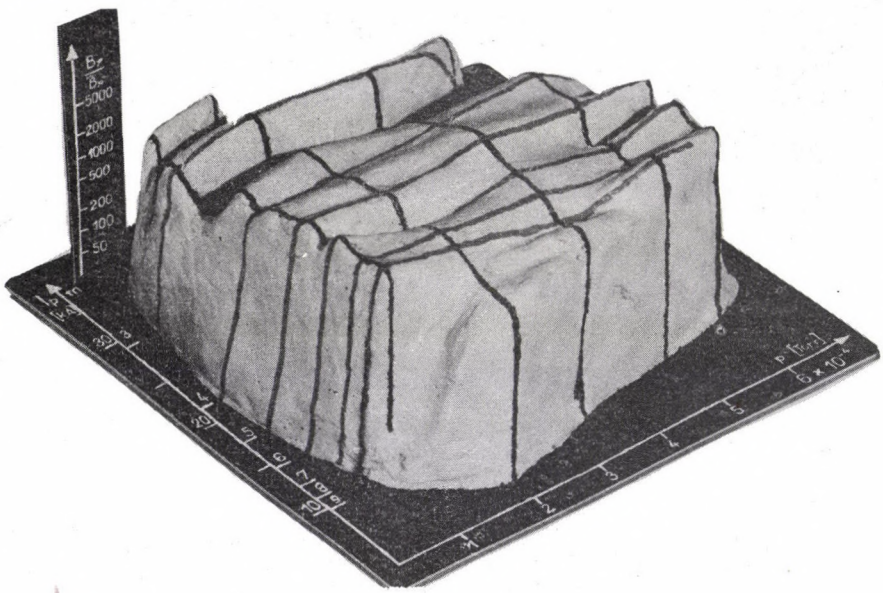

Fig. 8

The logarithm of the inverse MHD activity ($\tilde{B}_\varphi/B_\varphi$) as a function of the gas-pressure (p) and plasma-current (I_p) at B_z = 1 tesla; m is the poloidal mode-number

In *Fig. 9* the relative radiated power W_{out}/W_{in} as measured by means of a calibrated bolometer is plotted against the plasma current I_p. A typical figure is $W_{out}/W_{in} \approx 40\%$ which corresponds to a hydrogen-plasma slightly contaminated by heavier impurities ($Z_{eff} < 5$). In *Fig. 10* the conductivity is plotted at different gas pressures. The electron-temperature scale is based on Spitzer resistivity assuming $Z_{eff} \approx 3$. The reliability of this scale is supported by a more direct measurement of the electron temperature T_e making use of our Kevex Si(Li) windowless soft X-ray spectrometer. In two different tokamak regimes we obtained the soft X-ray spectrum shown in *Fig. 11*. The slope of the curves directly gives the maximal electron temperature in the area seen by the detector. If we compare these values with the ones deduced from the conductivity measurements we get an effective charge number $Z_{eff} \approx 3\text{-}3.5$.

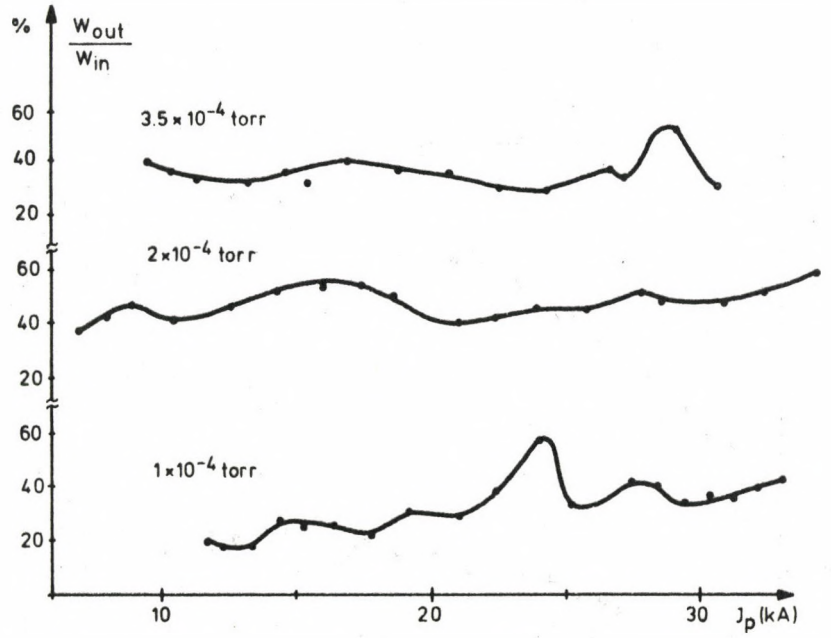

Fig. 9
Relative radiated power (W_{out}/W_{in}) as a function of plasma current (I_p)

We arrive at the given value assuming a parabolic current density distribution. The agreement of this value with those given by bolometric power measurements is good, and this shows the presence mainly of low Z impurities.

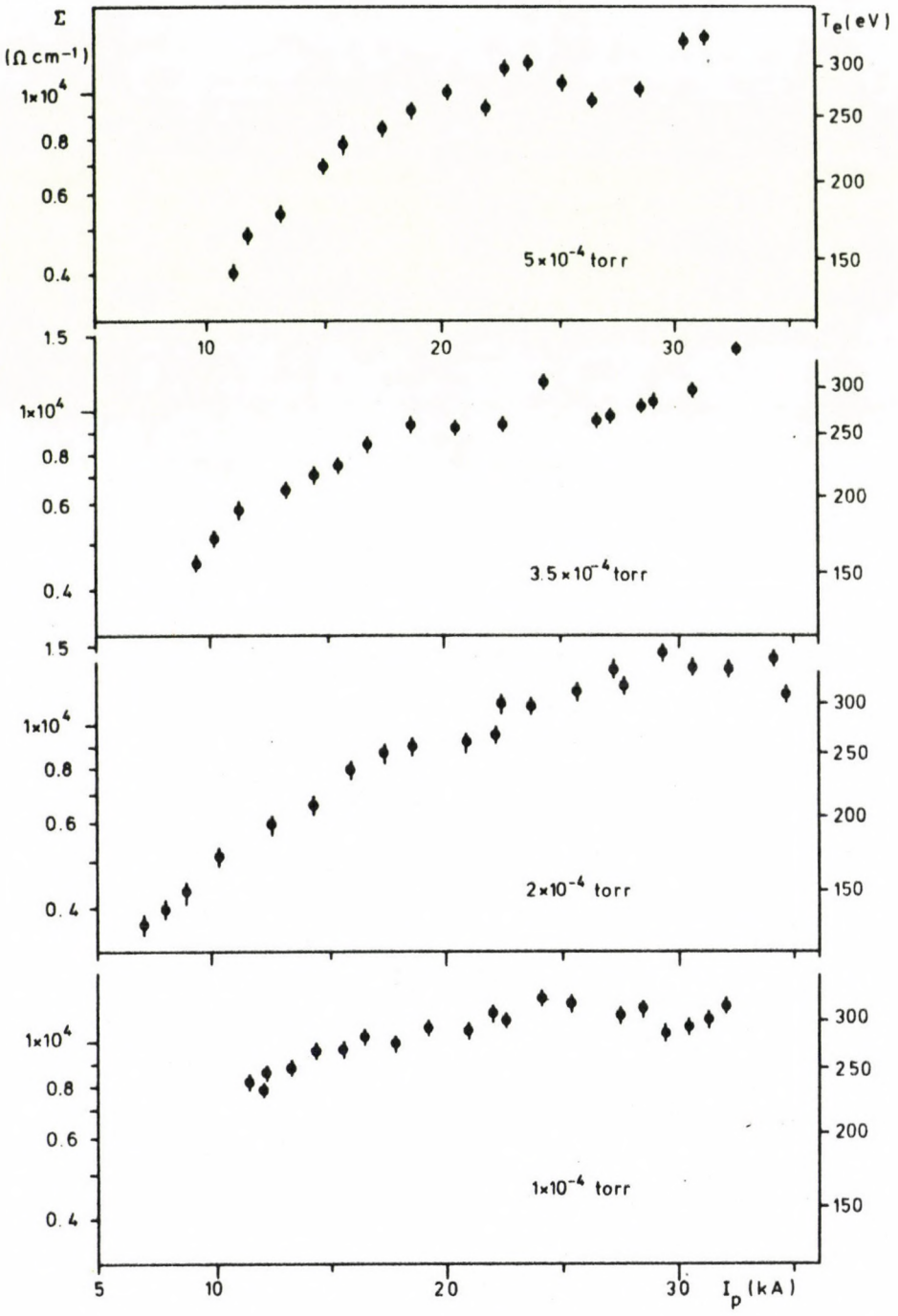

Fig. 10

Logarithm of plasma-conductivity Σ as a function of plasma current I_p at B_z = 1 tesla and at different gas-pressures as indicated

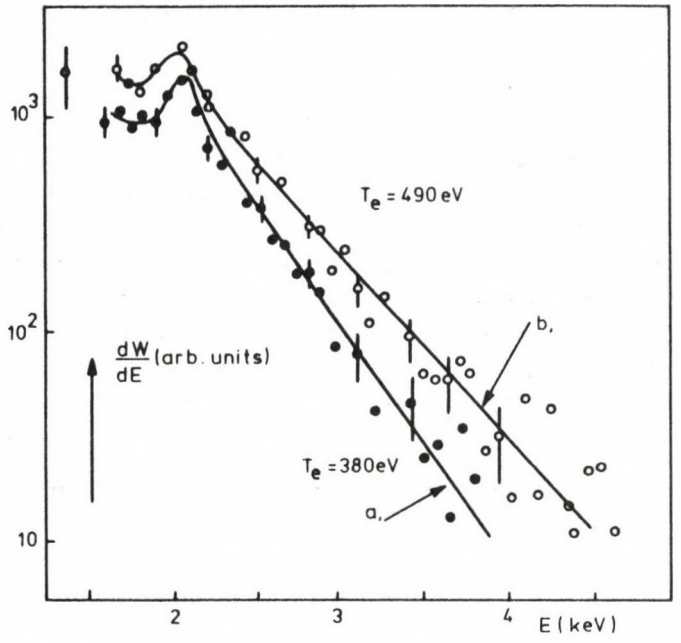

Fig. 11

Soft X-ray spectra of plasma for a) I_p=22 kA; b) I_p=30 kA. The toroidal magnetic field and the working pressure were B_z=10 kG and p=2.4x10^{-4} torr, respectively

The measurement of soft X-ray intensity along the small radius *(Fig. 12)* shows a similar electron temperature distribution, and does not rule out the assumed parabolic distribution of current density.

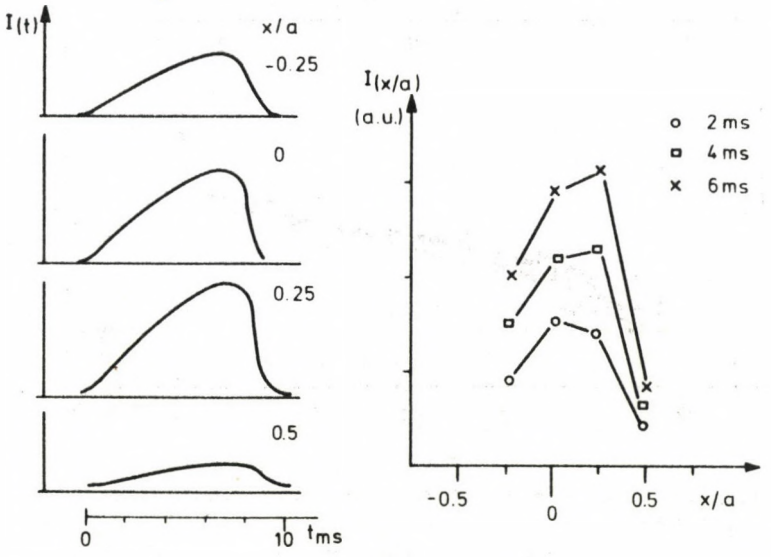

Fig. 12

Radial profile and time dependence of soft X-ray intensity

PUBLICATIONS: 24, 346, 445

INVESTIGATIONS ON THE SURFACE PLASMA WAVES IN THE MT-1 TOKAMAK

G. Bürger, G. Hrehuss, P. Kostka

MHD activity $\tilde{B}_\varphi/B_\varphi$, as measured by means of poloidally oriented magnetic probes, is known to be proportional to the amplitude of the waves on the plasma surface. These surface oscillations show more or less sharp resonances at plasma currents corresponding to rational values of the safety-factor defined by $q = 2\pi r^2 B_z/\mu_o IR$ where r and R are the minor and major radii, respectively, of the plasma ring, B_z is the toroidal induction, and I is the plasma current. While studying the performance of the plasma in the MT-1 machine more detailed experimental investigations have been performed on an apparent correlation between the period $T = 2\pi/\omega$ and the amplitude ξ_o of the surface oscillations.

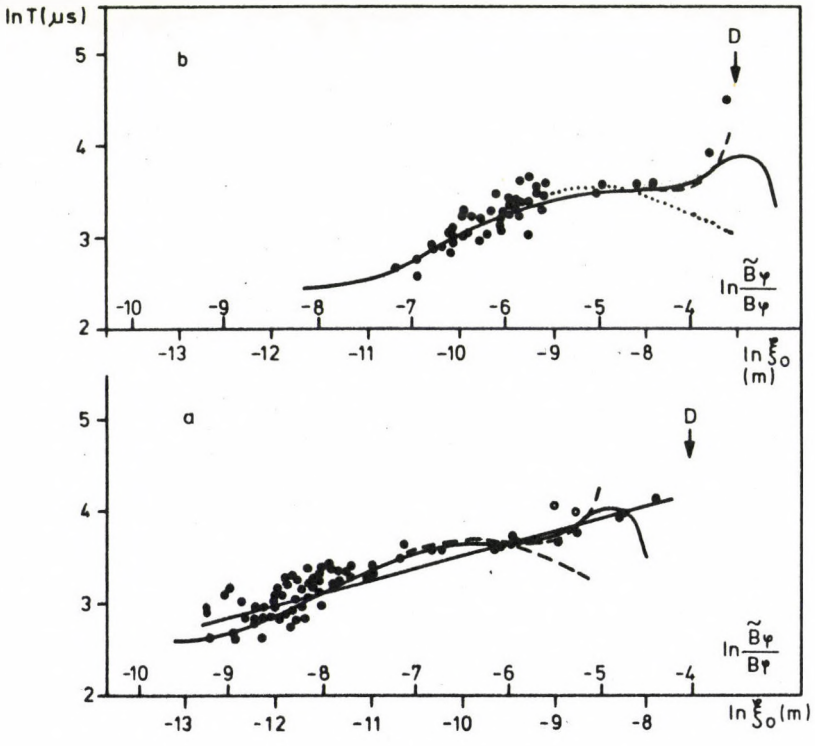

Fig. 13

Log-log plot of the measured functions of oscillation period T on B_φ/B_φ (and ξ_o) for runs (a) (B_z=0.96 T) and (b) (B_z=0.86 T), respectively, shown as full circles. The 3rd, 5th and 6th order approximations are shown by dotted, dashed and solid lines, respectively. The solid straight line corresponds to a scaling of $T \sim \xi_o^{0.26}$. The sign D points to the experimental disruption limit

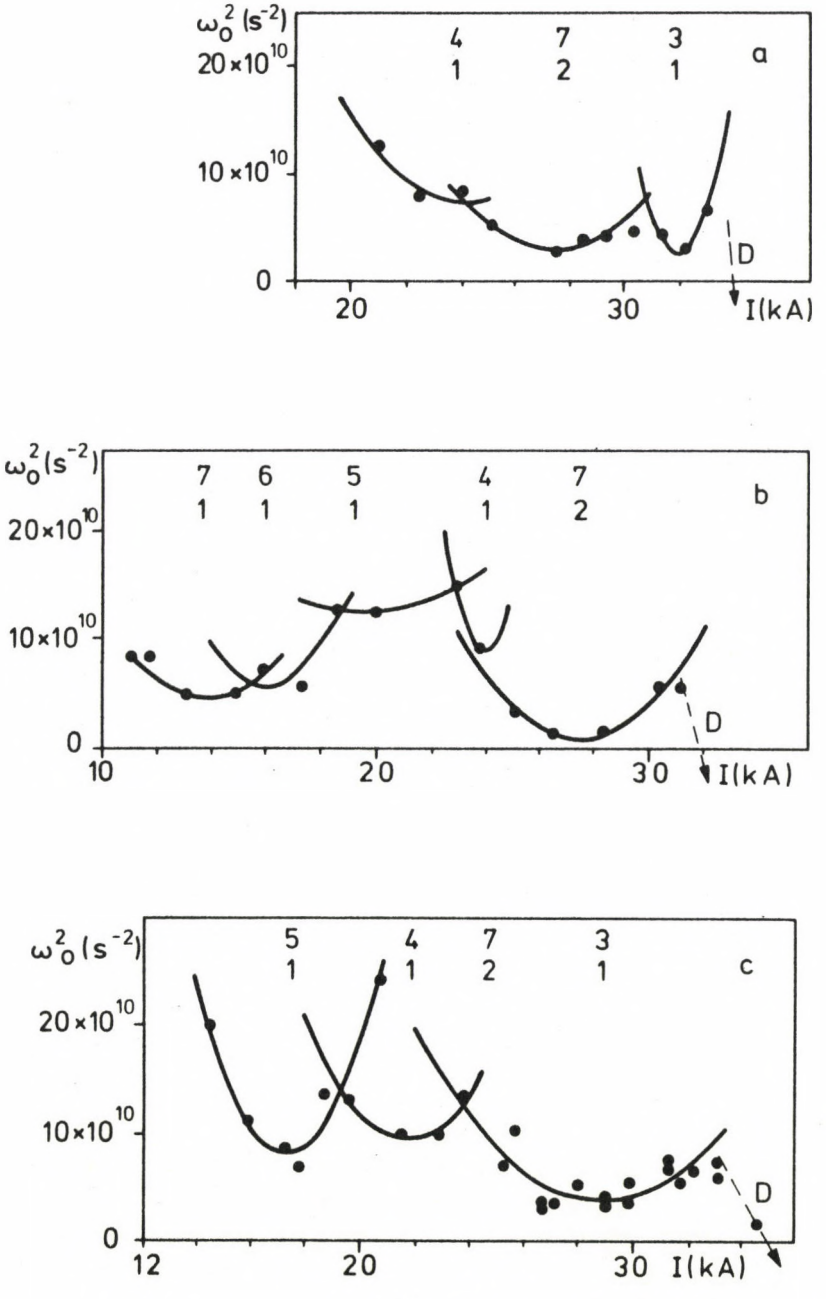

Fig. 14

Square of the frequency (in logarithmic scale) of the surface oscillations plotted against plasma current I. The solid lines correspond to theory. The numbers $\frac{m}{n}$ *show the assignment of the resonances. a: run (a)* 1×10^{-4} *torr. b: run (a)* 5×10^{-4} *torr. c: run (b)* 3.5×10^{-4} *torr*

The results are shown as full circles in *Fig. 13* for B_z = 0.96 T (run a) and B_z = 0.86 T (run b), respectively. The measured correlations suggest that the experiences can be described in terms of an anharmonic potential the shape of which is determined mainly by the pressure- and density-gradients of the plasma at the surface. Assuming that the waves are of magneto-acoustic type we were able to show that the non-linear hydromagnetic equation of motion in fact defines a potential with the required properties even if ideal conductivity was assumed. The corresponding calculated curves are shown as dotted, dashed and solid lines, respectively for increasing order of approximations as indicated.

The same theory seems to describe the shape of the hydromagnetic resonances as well *(see Fig. 14)*. A consequence is that the width of a resonance should be proportional to the pressure-gradient at the plasma surface thereby providing a useful means to estimate that important quantity.

INVESTIGATION OF THE PLASMA PARAMETERS OF PULSED He-DISCHARGE BY THOMSON SCATTERING

J.S. Bakos, P.N. Ignácz, J. Szigeti

The temporal evolution of the density and temperature of the electrons in He-plasma was measured in a pulsed He-arc discharge by the method of Thomson scattering. The parameters of the pulsed discharge were

He pressure	3 torr
tube length	200 mm
tube diameter	16 mm
discharge voltage	6 kV
discharge max. current	5 kA
discharge pulse width (FWHM)	10 μs.

The laser was a double-stage ruby-laser in multimode regime, Q switched by a Pockels-cell of KDP-crystal. The energy of the 30 ns laser pulse was about one joule.

A lens was used to focus the laser light along the discharge tube to its centre. The scattered light was focused perpendicularly to the laser-light direction into a monochromator slit. The scattered light was

detected by a photomultiplier and together with an energy monitoring-pulse, recorded by storage oscilloscope.

The Pockels-cell was synchronized so that we could set the delay from 4 to 60 μsec after the beginning of the He discharge. Using the formula from the theory of Thomson scattering we were able to obtain the electron temperature and density at a given moment after the breakdown of the He discharge. By varying the delay-time during the current pulse and the afterglow we could determine the time dependence of the temperature and density of electrons.

From *Fig. 15* it is evident that the temperature is relatively constant during the presence of plasma current (about 3 eV); in the region of afterglow from 16-34 μs it changes until it reaches the value of 1.4 eV. From 34 to 60 μsec it does not change again.

The density of electrons - as shown in *Fig. 16* in logarithmic scale - can be fitted with a straight line, i.e. after reaching a peak value of 4.7×10^{16} cm^{-3} at about 8 μs it decreases exponentially: with a time constant of 2.5×10^{-5} s.

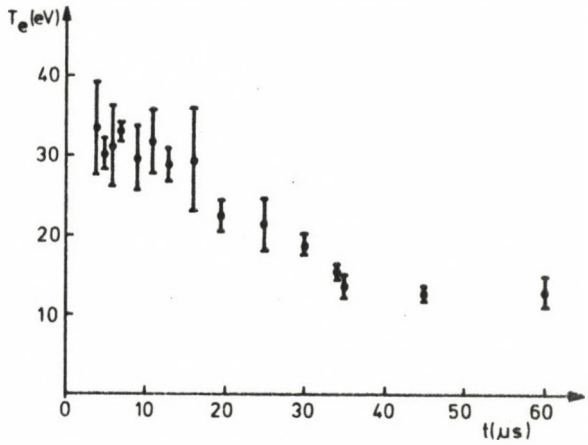

Fig. 15
Electron temperature (T_e) as a function of time (t)

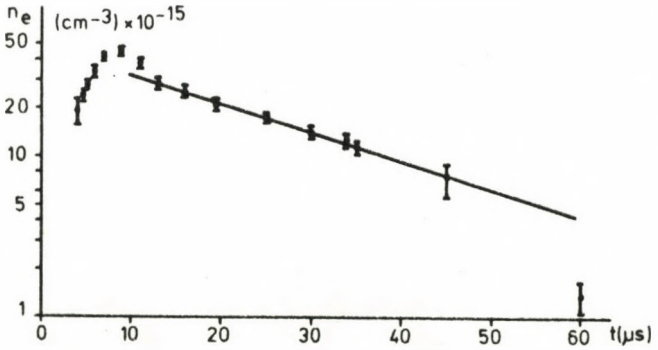

Fig. 16
Electron density n_e as a function of time (t)

Assuming that in the afterglow period the electron density is governed by ambipolar diffusion we could identify the measured time constant with the ambipolar diffusion time constant at the effective temperature of about 1 eV, because we have spatially and temporally varying temperature.

From this assumption we got for the diffusion constant, $D_a=4.4\times10^3$ cm^2/sec, which value seems to be reasonable in the light of earlier measurements.

PUBLICATIONS: 26, 27, 28

METHANOL LASER WAVELENGTH OF 118.8 μm

J.S. Bakos, Zsuzsa Sörlei, J. Szigeti

The temporal and local distribution of the electron density in tokamak plasma can be measured by interferometry.

In tokamak type machines the usual electron density is 10^{13}-10^{14} cm^{-3} therefore the most suitable wavelength of the probing beam is in the far infrared spectrum region.

We have constructed a methanol laser working on a wavelength of 118.8 μm to perform density measurements on the tokamak machines in the Kurchatov Institute of Atomic Energy, Moscow, USSR, and on the MT-1 of our Institute.

The methanol laser can be optically pumped by CO_2 laser radiation, as some vibrational transitions of the methanol vapour are in resonance with some CO_2 laser transitions. The methanol laser can operate at several wavelengths between 37 μm and 1.2 mm. One of the most powerful laser lines has the wavelength 118.8 μm, and it can be pumped by the P36 transition of CO_2 laser in the 9.6 μm band.

We have thus constructed a cw CO_2 laser tunable by a grating with a power of 30 W at the P36 transition needed for the pumping of the methanol laser. The length of the CO_2 laser resonator can be controlled piezoelectrically to bring its frequency into resonance with the absorption maximum of the methanol.

The experimental set-up can be seen in *Fig. 17.*

The methanol laser is a waveguide type with inner reflectors, whose resonator length can be controlled. The pump radiation is fed into the methanol laser resonator through a hole in the gilded rear cavity mirror. The output coupler is a hybrid-type mirror which is a z-cut crystal quartz plate coated with a dielectric layer of 100% reflection for the

pumping beam of 10 μm wavelength; the whole of its top is coated with gold except for a hole of a few mm diameter in the centre.

The laser power is about 10 mW for which a pyroelectric type detector is used.

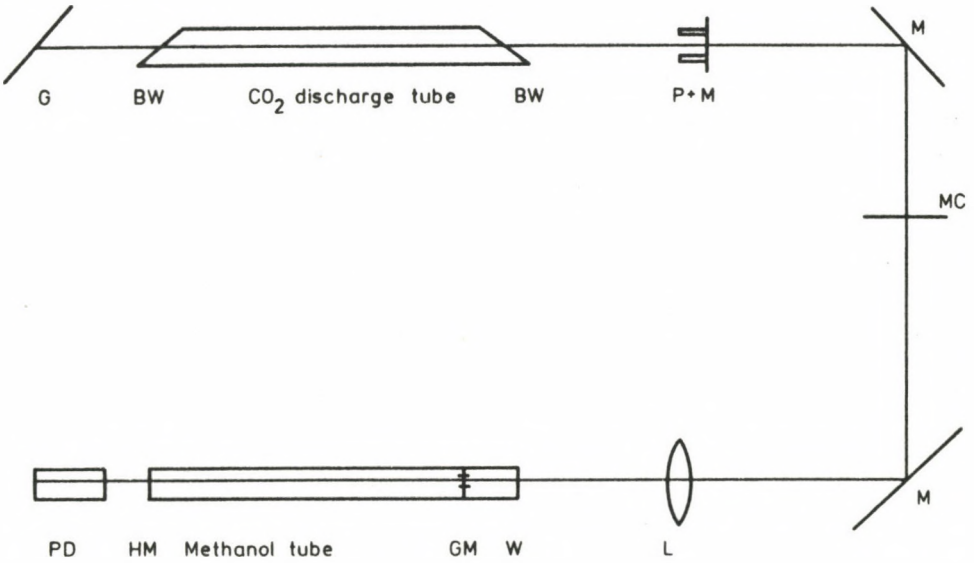

Fig. 17

Experimental set-up for CO_2-methanol laser system: G - optical grating; P+M - output mirror for CO_2 laser with piezo-assembly; BW - ZnSe Brewster window; M - gold coated mirror; MC - mechanical chopper; L - ZnSe lens; W - ZnSe window; GM - gold coated rear mirror with central hole; HM - hybrid mirror for methanol laser; PD - pyroelectric detector

PUBLICATIONS: 27, 29

TEMPORAL EVOLUTION OF SELF-FOCUSING IN LASER PRODUCED SPARK

J.S. Bakos, I.B. Földes, Zsuzsa Sörlei

We have been concerned with investigating the self-focusing effects in laser produced plasma. The experimental arrangement utilized is shown in *Fig. 18*. The light of the single mode and single frequency radiation of the ruby laser was focused in air by lens L1 and collimated behind the plasma by L2. The spatial distribution of the radiation transmitted through the spark was measured in the second focal plane by moving the fast photodiode along the x axis shot by shot (positions D1, D2, D3 and D4).

During the ionization process the polarization of the growing number of excited atoms distorts the shape of the laser pulse before the breakdown of air. Signals D2 and D3 show that the intensity of the laser pulse increases at the points of the focal plane of lens L2 near to the optical axis and decreases further from it. Self-focusing appears here as modulation of the spatial distribution of the original pulse, because there is still no noticeable absorption of the laser pulse up to this time.

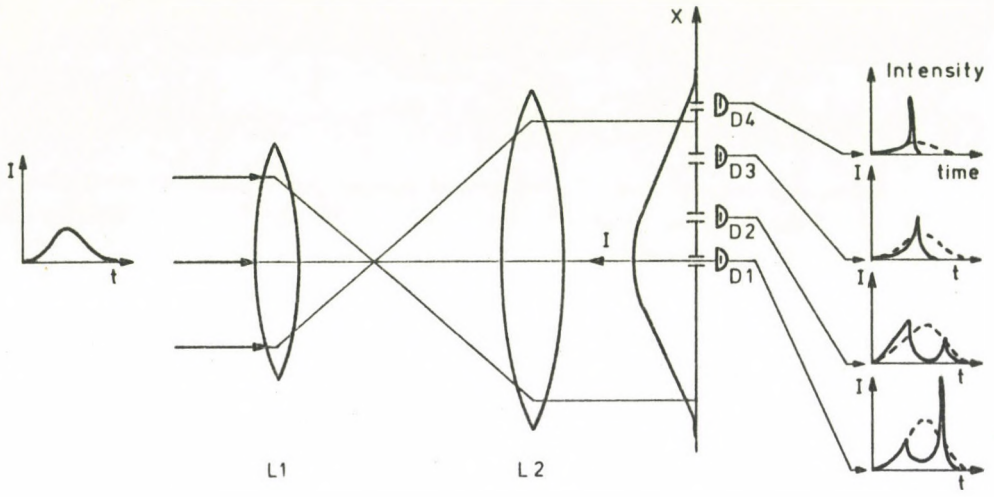

Fig. 18

Experimental arrangement for measurement of the self-focusing effects. L1 and L2: focusing and collimating lenses; D1, D2, D3, D4: fast photodiode in different positions

At the time of breakdown, a steep drop in the intensity can be observed (D1, D2). This is caused by the combined effect of the absorption, the reflection and the diffraction, i.e. scattering of the radiation on the plasma blob. At the same time the forward scattered intensity forms the narrow pulse outside and at the edge of the original light cone (D4 and D3 respectively). The narrow scattered pulse appears at the time of the breakdown observed at the optical axis. The scattering angle is observed to be about 10°, which gives 2.5 μm for the size of the plasma blob. The drop in intensity can be observed earlier at the observing point on the optical axis and later when further from it. The cause of this effect is that the breakdown begins in a small focal volume and propagates in the side direction thereby screening the original pulse at a larger distance from the optical axis later.

After the breakdown the plasma is heated nonuniformly by the Gaussian distribution of the radiation, and the redistribution of electrons begins.

Later, at higher electron temperature, the ponderomotive force also helps to form the annular distribution of the electrons, and it focuses the light into a narrow cone around the optical axis (D1). The time interval between the start of the breakdown and the appearance of the self-focused pulse is the time needed to form the annular distribution of the electrons.

In fact the spark is cigar shaped and not disk shaped, i.e. the annular distribution does not mean a ring but rather a hollow plasma distribution. It is the trapping of the radiation in the hollow plasma that produces the short and narrow pulse of D1.

PUBLICATIONS: 25, 391, 392, 393

PLASMA-WALL INTERACTION STUDIES

J. Gyulai, E. Kótai, T. Lohner, A. Manuaba, G. Mezey, F. Pászti, L. Pócs

Plasma contamination on probes placed in tokamaks can be investigated by $^{14}N^{+}$ backscattering with the sensitivity of 10^{10} atom/cm^2 for heavy elements. During MeV nitrogen analysis to detect sub-monolayer heavy impurities, a "beam effect", i.e. high impurity loss, was found. To clarify the situation a systematic study was done on gold evaporated films (in the thickness range 0.5-3200 atom/nm^2) onto silicon. Results suggest that the sputtering of cascades induced by energetic nitrogen ions is responsible for the phenomenon. The sputtering yield of gold was a linear function of surface coverage in the range 0.5-130 atom/nm^2. For thick overlayers ($\geq$800 atom/nm^2) a saturation value of S$\approx$0.8 gold/N^{+} was found. A rough theoretical model is outlined for a quantitative description of overlayer sputtering in the MeV energy region.

Blistering formation for 352 MeV helium ions up to the dose of 3.4×10^{18} ion/cm^2 was also investigated on a cold-rolled gold target. At the highest dose a huge (diameter $\cong$ 0.8 mm) blister with a dome-like lid was found. Because no exfoliation was observed by scanning electron microscope (SEM) measurements, the blisters were opened mechanically. In this way the topography of the skin (deckeldicke) both outside and inside as well as of the surface structure of the bottom of the blister was studied. The first interesting observation was that the blister grew by sudden size changes. In addition, several much smaller blisters were found inside the big one.

PUBLICATIONS: 211, 212, 311, 538, 539, 548, 564, 570, 597

MT-1 TOKAMAK: INSTALLATION, OPERATION AND DEVELOPMENT

G. Bürger, P. Kostka, Z. Mészáros, Cs. Seres, M. Szulman

The installation and starting-up of the MT-1 tokamak device *(Fig.19)* were completed in 1979. The tokamak itself was made in the Soviet Union, but all the necessary conditions relating to the installation and setting up had to be met here in the Institute. Not only was it important to ensure that suitable buildings and facilities (water cooling system, crane, among others) were available; of equal inportance were the construction, the manufacture and the mounting of all the supply-, control-, and measuring systems.

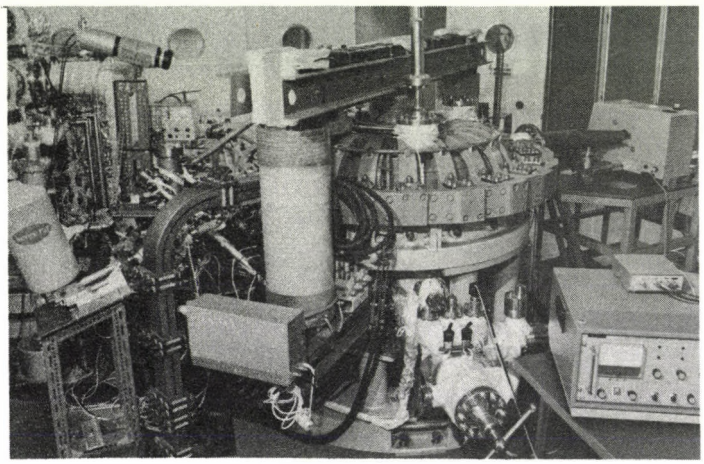

Fig. 19

View of the tokamak device with some of the connecting plasma diagnostic research instruments

The main parts of the work were as follows:

- mounting of two condenser-banks; one of them for producing the 680 kJ energy at a 5 kV voltage-level for the toroidal magnetic field; the other for the ohmic heating in plasma - 88 kJ energy at a 5 kV voltage-level;
- making of a feeder with 125 V and 6.5 kA to produce the 0.01 T magnetic field necessary for stabilizing the plasma ring;
- elaboration of a vacuum control system and a forevacuum system, which are connected to the ultrahigh vacuum system of the tokamak;
- setting up a control system for starting the supply-units of the tokamak. The control system carries out all the necessary supervisory work including the operation of the safety doors;

- installation of a telemetering-system between the control-room and the diagnostic instruments of the tokamak. This particular system is designed to measure the plasma-position, the plasmacurrent, the loop-voltage and the exciting currents of the magnetic fields. The minicomputer - installed next to the control-room - provides the possibility to create a computerized measuring system.

Installation, starting-up and adjustment of the working-parameters were carried out in cooperation with specialists of the Kurchatov Institute of Atomic Energy and the Efremov Institute for Electrophysical Equipment, USSR.

Main data and parameters of the tokamak are as follows:

plasma major radius	0.4	m
plasma minor radius	0.09	m
operating toroidal magnetic field at present	1.2	T
plasma current	10-35	kA
plasma loop voltage	2.5	V
lifetime of plasma discharge	8.5	ms
electric conductivity of plasma	10^4	S
average electron temperature	300-400	eV
safety factor q	2.7	
minimum pressure in liner	10^{-6}	Pa
operating pressure of hydrogen gas before discharge	$1\text{-}6\times10^{-2}$	Pa

Development work is continuing on the electrical and on the magnetic system of the device. Regular physical research was started in January 1980.

DATA ACQUISITION SYSTEM OF THE MT-1 TOKAMAK

L. Gyimesi, Á. Szentgáli

We have mainly been concerned with preparational work concerning the data acquisition system of the MT-1 tokamak.

Data acquisition of the tokamak will be performed by a CAMAC system controlled by several microprocessors. This part of the system, already in operation, is due to be extended by a TPA 1140 small computer in the near future. In view of this, the configuration of the CAMAC system has been arranged so as to enable program development and testing as well as introductory measurements.

Software development was essential in the course of this preparational stage. Among others, two main software units have been developed.

The UP80 Resident Utility Package which can reside in RAM as well as ROM memory gives essential help to develop and test user programs on the CAMAC system itself. The ICC-80 CAMAC Macro Library Pack contains a great number of macros performing any kind of CAMAC commands. The utilization of these macros means that CAMAC programming becomes a very easy job by using a symbolic-like notation.

This macro library will be further developed to incorporate floating-point calculations. Another software unit now under development is a monitor program which enables information exchange between interconnected CAMAC subsystems each driven by its own microprocessor.

PUBLICATIONS: 634, 689

ENERGY-RESOLUTION AND LIGHT-GAIN OF GAS-PROPORTIONAL-SCINTILLATION COUNTERS

G. Hordósy, Gy. Hrehuss

In many applications of gas-proportional-scintillation (GPS) counters optimum energy resolving power and high light-gain are of primary importance. Such is the case in the field of extreme-soft X-ray spectrometry (from 1 keV down to 100 eV quantum energies) where GPS counters surpass, in many respects, even the best commercially available Si(Li) detectors. The aim of the present work has been to develop a statistical theory for a quantitative description of both the energy resolution and the light gain of the counters in question.

It was found that the good performance of the GPS counters is largely due to a violation of the independence of succeeding inelastic collisions of the drifting electrons, therefore to find their realistic energy-distribution function the time-dependent Boltzmann equation had to be solved after which a corresponding statistical analysis had to be applied. *Figures 20* and *21* show the calculated reduced light-gain (U/p) and the relative linewidth ($\Delta U/U$) (FWHM) for the 5.9 keV radiation of ^{55}Fe as a function of ε/p together with the measured points, where ε is the electrical field strength and p is the gas pressure in the GPS chamber. The calculated characteristics are in good agreement with the measured ones.

PUBLICATION: 661

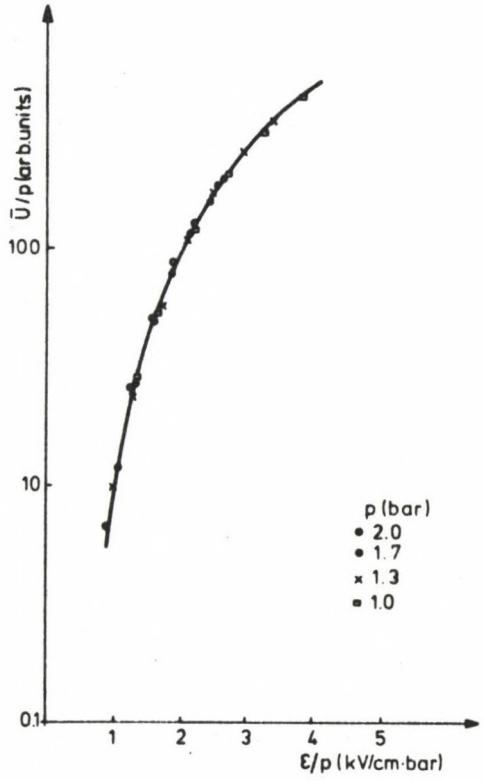

Fig. 20

Reduced light-gain ($\bar{U}/p$) as a function of reduced field-strength (ε/p). Points measured at different pressures are compared with the function (solid line) as given by the theory

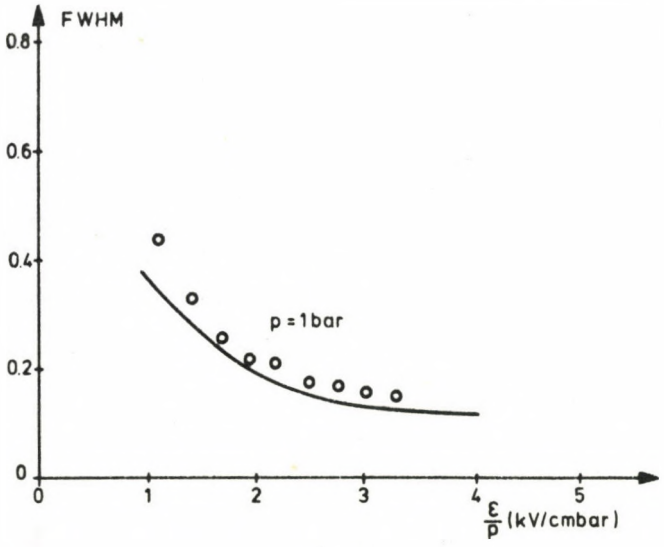

Fig. 21

Relative linewidth (FWHM) as a function of ε/p at p = 1 bar. The points are measured using the 5.9 keV radiation of a ^{55}Fe source; the solid line is calculated using the same parameters as in Fig.20

OPERATION AND DEVELOPMENT OF THE 5 MeV ELECTROSTATIC ACCELERATOR

E. Klopfer, P. Kostka, J. Roósz, Cs. Seres, M. Szulman

In 1979 and 1980 the EG-2R Van de Graaff ion accelerator was running for experiments in nuclear and solid state physics, biophysics and plasma-physics. During this time the accelerator was working in the 0.8-4.8 MeV energy range; the analysed and stabilized ion current at each of the four target places was 1-5 μA; the short-time energy stability was $(2-4)\times10^{-4}$, the long-time stability about twice this value; protons, deuterons, $^{4}He^{+}$ and $^{14}N^{+}$ ions could be accelerated.

The working hours of the machine (current on the target) were: 2385 hours in 1979, 3865 hours in 1980.

In addition to the operation and maintenance of the accelerator, developments and improvements were carried out:

- 2 plexiglas rods of the supporting structure of the high voltage column were changed as a consequence of damage by high voltage breakdowns;
- acceleration of $^{14}N^{+}$ ions was made possible up to energies determined by the mass-energy product of the analysing magnet (2 MeV in case of nitrogen);
- the application of turbomolecular pumps enabled the vacuum of the beam-lines to be improved by 1/2-1 order of magnitude, its composition was made better;
- improvements were made on electronic devices of the high voltage terminal (voltage stabilizer of the local power alternator, on some units supplying the rf ion source) and on some units of the beam transport system (quadrupole - lens supply, excitation stabilizer of the magnet supplies);
- an oil-free gas-compressor was set to work in the gas-system of the insulating gas circuit of the accelerator.

The exchanging of other obsolete units for up to-date ones is being continued.

PUBLICATION: 622

BIOPHYSICAL RESEARCH

I. Demeter, P. Hargittai, Vera Jánossy, L. Keszthelyi, A. Orosz, Z. Szőkefalvi-Nagy, L. Varga
*Visiting research worker: Katalin Hollós-Nagy**

In the last two years our group has continued its twofold activity: further results were obtained in accelerator-based nuclear analyses; essential progress has been achieved in developing the extensive studies on the basic functional mechanism of neuromembranes.

As far as nuclear analysis is concerned, the important problem of the determination of the trace element content of single human hairs was studied in more detail. Our earlier preliminary findings that the S/C and S/N ratios were approximatively constant along a single hair (see *Fig.22*)

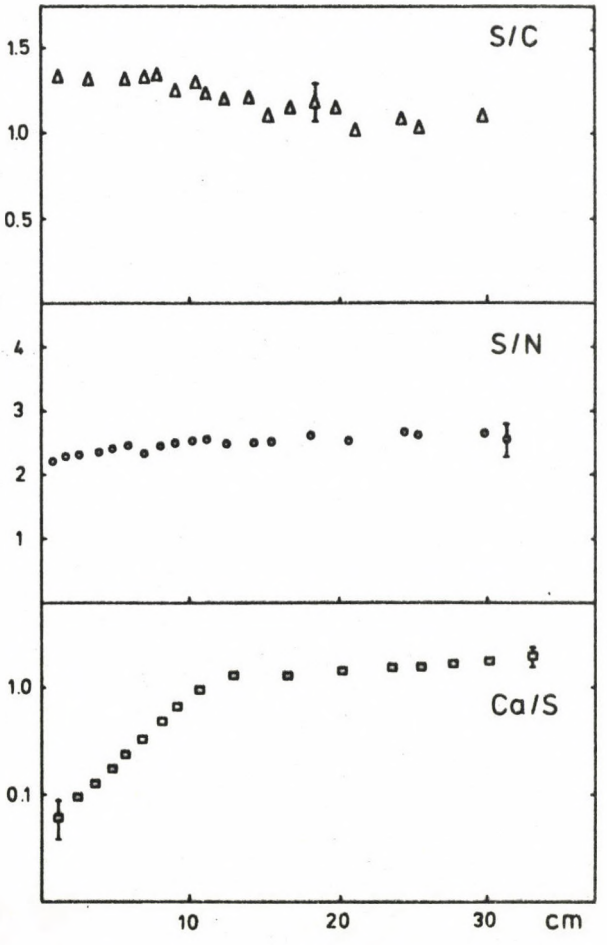

Fig. 22

Dependence of the ratios S/C, S/N and Ca/S along a single human hair on the distance measured from the hair root

* Institute of Biophysics, Biological Research Center, Szeged, Hungary

were confirmed for hairs up to 40 cm long taken from different donors. As a conclusion of these measurements the sulphur content was suggested as an appropriate quantity for normalizing the results of particle induced X-ray emission (PIXE) measurements of the elemental composition of human hair. The variations in the concentrations of heavier elements were also studied along the hairs by proton induced X-rays using the S content for normalization. Calcium showed the most marked variation, its concentration increased roughly exponentially as a function of the distance measured from the root of the hair *(Fig. 22)*. This result warns us that any interpretation of the Ca content of hair must be considered very cautiously.

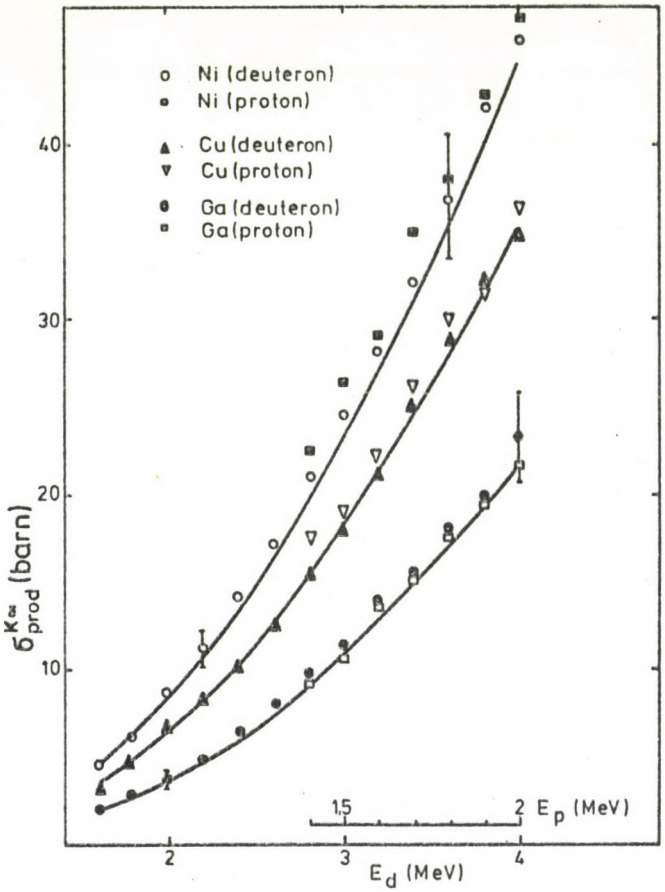

Fig. 23

K_α X-ray production cross sections for Ni, Cu and Ga measured by deuteron and proton bombardment. The energy scale for protons is also inserted, the solid curves are calculated using a semiempirical expression from the literature

Besides the analytical applications, the study of deuteron induced X-rays provides important information about the nature of ion-atom collisions. Therefore a series of K X-ray production cross-section measurements were performed on thin P, S, Cl, K, Ni, Cu and Ga targets by increasing the deuteron energy in 0.2 MeV steps from 1.6 to 4.0 MeV. The comparison of cross-sections obtained by deuteron and proton bombardment confirmed the validity of the scaling law which states that particles of the same charge and the same velocity have the same ionization cross-sections *(Fig. 23)*. According to this result the semiempirical expression developed in the literature for proton bombardment can also be used to evaluate quantitative deuteron induced X-ray emission analyses.

For the investigation of the biophysics of neuromembranes a new laboratory was built and equipped. Besides the intellectual and even technical contributions to this installation the preparatory works were done in two directions. First of all it is required that suitable biological objects be prepared, but at least of equal importance is the development of the most suitable physical methods for their study.

One of the most interesting parts of a system of neurons is the synapsis where the interneuronal transmission of the nerve impulses takes place. Following the instructions given in the literature so called synaptosomes were prepared from rat cerebral cortex. From the morphological point of view the synaptosomes were identified by electronmicroscopy, but the activity of the marker enzymes was also checked. To monitor the relative changes in the transmembrane electric potential in synaptosomal suspension a specific method was adopted. In this method the synaptosomes were treated by a voltage-sensitive fluorescent dye and the changes in the fluorescence of those treated synaptosomes turned out to be directly proportional to the membrane potential.

The most relevant parts of the synaptosomes, the so called synaptic junctional complexes, can also be isolated. These structures consist of a highly specialized part of the pre- and postsynaptic plasma membranes joined by the synaptic cleft. Synaptic junctional complexes were successfully isolated from the cerebral cortex of rabbit brains using successive density gradient centrifugation techniques. The purity of the obtained fractions and the preservation of the membrane-pairs were checked by electronmicroscopy. Attempts were also made to test the biochemical activity of the junctional complexes.

For certain measurements an oriented assemblage of the membrane fragments is preferable. Orientation means the parallel ordering of the membrane fragments in such a way that the cytoplasmic side of all fragments faces in the same direction. A method to induce orientation of membrane fragments was worked out. The measure of the orientation can be

tested with the help of light scattering or, when the fragments contain well defined chromophores, by measuring the linear dichroism. The results of such linear dichroism measurements are reproduced in *Fig. 24* where the time course of light intensity changes behind the absorbing purple membrane solution for different orienting field strengths is displayed. The sign ⊥ means that the measuring light was polarized perpendicular to the direction of the electric field; || refers to parallel polarization.

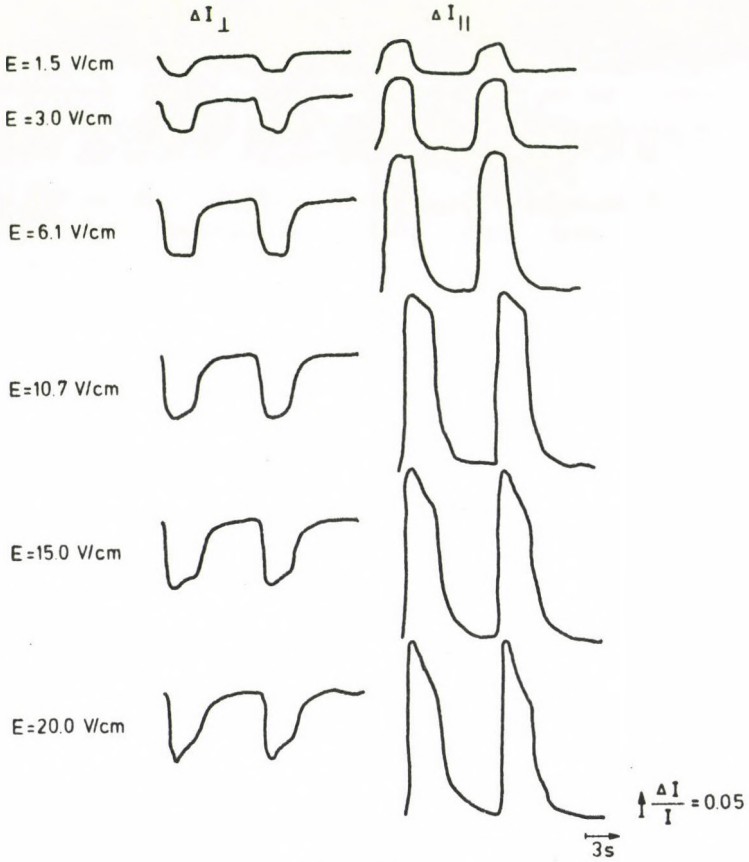

Fig. 24

Time course of light intensity changes behind the absorbing purple membrane solution for different field strengths. The two sets of curves belong to different polarizations of the measuring light.

A static method of orientation was also studied. Thin collodium films were treated by charged lipids and the membrane fragments could be glued onto this thin holder.

PUBLICATIONS: 69, 86, 87, 186, 522, 523, 591, 639

NUCLEAR ELECTRONICS

INSTRUMENTS AND SYSTEMS

O. Baka, I. Bereczky-Kerényi, Gy. Erdélyi, J. Erő, M. Faragó, G. Farkas, F. Ferenczy, I. Hernyes, J. Jani, Zsuzsa Juhász-Kovács, M. Kanyó, J. Koch, T. Kovács, Gy. Kozma, L. Lohonyai, T. Mózes, I. Nádday, J. Nagy, G. Pákay, J. Pazonyi, M. Sándor, L. Szabó, S. Szalai, A. Szepesváry, I.T. Szücs, P. Takács, Gy. Thaler, Márta Tóth-Bodonhelyi, J. Urbán, I. Veress, J. Windberg, P. Zalán, A. Zarándy, Z. Zimányi

In connection with the high energy physics research activity of the Institute the development of the track-chamber picture evaluation system (RIMA) apparatus has been continued for the purposes of automatic evaluation of streamer chamber photographs. The basis of the apparatus is an integrated circuit containing a linear array of 1728 photodiodes which senses the picture moved below it. The complete electronics and on-line programme of the picture sensing circuitry, the complete control of the stage moving and film transport system as well as the 512x512 picture element graphic raster display were completed by the end of 1980. The design of a fast hardware processor has begun to replace the picture-element identification programme.

The modernization of the digitizing microscopes and of the string coordinate measuring system (mangio spago) was finished for the semi-manual evaluation of events that are too complicated to be evaluated by the automatic system. For this purpose, a measuring system consisting of CAMAC units was built which is on-line with a TPA 1140 computer.

For cosmic ray measurements a telescope consisting of 128 proportional tube-detectors has been installed. A high precision gas mixing apparatus provides for the long-term stability of measurements lasting for several years. An autonomous CAMAC system is used to collect the measurement results.

An 8-channel fast waveform digitizer and an 8-channel fast pulse peak analyser have been developed for measurements on the experimental tokamak of the Institute. Both CAMAC modules have 64 Kbyte memory for the temporary storage of the considerable volume of data arriving during the tokamak cycle.

For use in laser diagnostics measurements on the tokamak, a Pockels cell driver was developed. The instrument generates high voltage (max. 10 kV) and fast (rise-time less than 50 ns) double pulses. By applying the pulses of the device to a Pockels cell placed in the path of the light beam of a laser and by adjusting the amplitude of the two pulses, two accurately timed light pulses with variable amplitude can be obtained from a single laser discharge.

In cooperation with the Nuclear Research Institute of the Hungarian Academy of Sciences, Debrecen, Hungary, a low dead time, programmed autonomous CAMAC amplitude analyser has been developed. The results of measurements can be displayed on a TV monitor with 256x256 resolution. With the help of CAMAC-BASIC and assembler programs the microcomputer of the apparatus provides on-line data processing. Calibrating, normalizing, smoothing operations can be performed on the selected spectrum, and in addition there is provision for calculating the characteristic parameters of a selected peak.

A cartridge tape data storage unit was developed to replace the punched tape peripheral devices used earlier in great quantities with a more reliable device whose operation is much easier. It facilitates the further processing of the results of various physical measurements.

The development of a nanosecond delay and a constant fraction discriminator was completed to extend the range of the analogue CAMAC (CAMALOG) instrument family. For positron annihilation measurements a double fast discriminator - fast coincidence unit was constructed.

An updated version of the "autoPRODET" instrument was constructed. This instrument is used for agricultural applications to determine the protein content of animal fodder. The instrument is connected to a programmable calculator with the help of which it determines the percentage of the protein content by analysing the gamma spectrum emitted by the fodder exposed to neutron irradiation.

The measuring system and its operating programme designed for the measuring stations of the Enviromental Radiation Protection Control System of the Paks Nuclear Power Plant has been completed.

In the multiwire proportional chamber programme 5 chambers of 600x1000 mm effective surface have been shipped to the Joint Institute for Nuclear Research, Dubna, USSR. For neutron spectroscopy purposes a 256x256 mm effective surface chamber has been completed, the construction of a chamber of similar size with cathode read-out is in progress. For the Institute of Nuclear Physics, Leningrad, USSR, the development of a 512x512 mm effective surface chamber; for JINR, Dubna, USSR, the development of a high spatial resolution 256x256 mm effective surface chamber is in progress.

In the space research programme the model of the KSD-1/A semiconductor detector telescope and analogue data processing unit of the TÜNDE apparatus, analysing charged particles with respect to energy and type, has been designed. The technological version of the KSD-1/B data collecting and processing unit was built and tested.

PUBLICATIONS: 85, 316, 360, 361, 549, 593

INSTITUTE FOR
SOLID STATE
RESEARCH

THEORETICAL SOLID STATE PHYSICS

J. Bergou, P. Fazekas, G. Forgács, F. Iglói, J. Kollár, Nóra Menyhárd, E. Praveczki, T. Siklós, J. Sólyom, P. Szépfalusy, I. Tüttő, S. Varró, K. Vladár, F. Woynarovich, A. Zawadowski

The general properties of the dynamic renormalization group have been studied by introducing non-linear scaling fields and scaling variables. In isotropic antiferromagnets the dynamic characteristics of the total magnetization were calculated and we were able to interpret quantitatively the results of the neutron scattering experiments in $RbMnF_3$.

In the field of ferroelectric phase transitions in cooperation with the Joint Institute for Nuclear Research, Dubna, USSR and the Institute Boris Kidrič, Vinča-Beograd, Yugoslavia, we finished the investigation of the effects of tunnelling. We showed that the tunnelling can lead to considerable effects in the low temperature region and in the case of the order-disorder phase transitions.

The Migdal recursion method has been generalized and applied to random magnetic materials, spin glasses and to the dynamic phenomena taking place in the Potts model.

Scaling equations have been derived for the isotropic version of the two-level model of metallic glasses and we verified the absence of the logarithmic contribution to the resistivity.

A qualitative microdomain model has been worked out in order to interpret the effect of different positively charged impurities on the charge density wave-transitions in 1T-TaS_2.

We continued the investigation concerning the development of high power hollow cathode lasers and the interaction of free electrons with intense electromagnetic field.

A new model with spin-flip interaction has been proposed for the description of quasi 1D systems. In the model the spin and charge density degrees of freedom are separable. The model can be treated more easily than the back-scattering model examined earlier and at the same time the physical properties of the two models are similar to each other.

The fluctuation phenomena taking place in the neighbourhood of the phase transition point in TTF-TCNQ were interpreted in the frame of a generalized Ginzburg-Landau theory. The magnitude of the pseudogap was determined and we found that its effect on the physical quantities is negligible above the critical region. In the frame of the same theory we calculated the concentration dependence of the temperature of conductivity-maximum and other characteristic quantities by taking into account the effect of impurities. The results were in good agreement with the experiments.

We determined the lower edge of the singlet excitations of a Heisenberg chain and showed that for an infinite chain this edge coincides with the lower edge of triplet and higher multiplet excitation spectra determined earlier. We showed that the excitations of a half-filled Hubbard chain can be divided into two groups. These two kinds of excitation can be identified with the excitations of the charge density and spin degrees of freedom, respectively, in the limit $U \gg t$ (U and t characterize the interaction and the bandwidth respectively).

Within the frame of the theory of superconductivity we examined the tunnelling spectra of high temperature superconductors. New results were obtained concerning the optical properties of transition metal superconductors and the electron-phonon interaction. Furthermore, we studied the acoustic plasmon excitations of superconducting compounds.

In cooperation with the I.V. Kurchatov Institute of Atomic Energy, Moscow, USSR we showed in connection with the structure of dilute alloys that in the calculation of the deformation of the host lattice around the impurity the three-body forces have to be taken into account already in the lowest order structure-dependent calculation as well. The theory reproduces successfully the experimental fact that in contrast with the lattice constant, the bulk modulus is not a linear but a strongly convex function of the concentration.

The study of the electronic structure of metals has been continued. Our purpose is to develop a method which is capable of determining the electronic structure and related physical quantities for a structurally disordered system with two or more constituents. The structure and the cohesive properties of several liquid metals were determined using the pseudopotential method. A new perturbational method has been developed to determine the structure and the thermodynamic properties of a system in terms of the correlation functions and the thermodynamic characteristics of a reference system.

PUBLICATIONS: 47, 48, 49, 67, 68, 107, 108, 115, 120, 121, 161, 170, 199, 233, 251, 280, 291, 294, 305, 306, 307, 308, 309, 318, 319, 331, 332, 351, 408, 409, 410, 411, 412, 413, 414, 448, 449, 450, 451, 452, 490, 491, 507, 528, 561, 567, 584, 624, 625, 635, 636, 637, 682, 683, 684, 685, 686

RESEARCH ON MAGNETISM

Gy. Kádár, G. Pető, I. Pintér, I. Szabó, Gy. Zimmer

Our work has been aimed at the investigation of physical phenomena of fundamental character in magnetic garnet single crystal layers and in various types of thin films that are useful materials for applied technological research on magnetic bubble memory devices.

For the study of the dynamic response of domain walls in bubble garnet layers to magnetic field pulses a single exposure optical sampling microscopy equipment has been used with a 6 ns laser light pulse properly timed with respect to the field pulse. The velocity of the domain wall is a linear function of the drive field until a saturation velocity value at a critical value of the field, both characteristic of the given garnet material, is reached. We have found that the dependence of the saturation velocity on material parameters can be described by different functions for bubble translation and bubble expansion experiments. In high drive fields well above the mentioned critical value a structural change of the moving domain wall, the so called dynamic diffuse wall, was able to be observed during bubble expansion. We have measured the displacement and the width of the diffuse wall as a function of time in a wide range of the drive field and of the static in-plane magnetic field.

We have studied the structural properties of thin films used for the fabrication of bubble memory devices. In evaporated multilayer Al and Cu thin film sandwiches a surface diffusion of the Cu atoms along the grain boundaries of the Al film was found during annealing. The grain size of Al-Cu alloy thin films depends on the Cu concentration and in the 0.1-8.0 w % Cu concentration range it decreases by about an order of magnitude with the increase of the Cu content. The powerful thin film analytical methods of ultraviolet photoelectron spectroscopy and Auger electron spectroscopy were used for studying the electronic structure of amorphous silicon films and metallic glass Fe-B alloys.

PUBLICATIONS: 128, 150, 605, 606

MAGNETIC BUBBLE MEMORY RESEARCH

M. Bak, Éva Baka-Vázsonyi, M. Balaskó, L. Bodócs, I. Eördögh, E. Fellegi, Irén Fellegvári, L. Gosztonyi, L. Házkötő, L. Joó, Gy. Juhász, Z. Juhász, Gy. Kádár, Judit Kántor, Róza Kertes, B. Keszei, E. Krén, M. Marton, Z. Nyitrai, J. Paitz, Márta Pardavi-Horváth, G. Pető, I. Pintér, L. Pogány, Judit Sasvári, G. Serfőző, G. Szabados, I. Szabó, B. Szigeti, J. Vandlik, G. Vértesy, Zofia Vértesy, Gy. Zimmer, Éva Zsoldos-Ravasz

Our work in this field includes a very wide range of technological research activities and the following description is far from being a detailed account of all the results obtained during the fabrication of operating packaged bubble memory device samples.

We have grown more than a hundred gadolinium-gallium-garnet (GGG) defect-free single crystal boules of 20 mm diameter in an automated Chochralsky-type equipment. Another equipment for growing 55 mm diameter crystals, constructed in the Institute and put into operation in late 1978, has been used for producing 2" GGG crystals. Several thousand substrate wafers have been sliced from the GGG single crystal boules with a (111) crystallographic orientation of 0.1-0.2 degree accuracy and then polished to get a defect-free crystal surface. X-ray topography and optical methods are used for the quality control of the single crystal wafers.

Magnetic garnet single crystal layers have been grown by liquid phase epitaxy on several thousand substrate wafers in automated, temperature controlled furnaces designed and constructed in the Development Engineering Section of the Institute. The magnetic bubble domains can be stabilized in these magnetic garnet layers and the bubble diameter depends on the layer composition and thickness. Magnetic garnet wafers of 5 μm and 3 μm bubble diameter have been produced in large quantities and preliminary experiments have been carried out to produce 1 μm bubble diameter material. Ne^+ ion implantation is applied for the elimination of hard bubble formation and an ion-implanter was constructed for this purpose.

The bubble manipulating structures in a bubble memory chip, i.e. the active conductor-loops of evaporated Al-Cu thin film, the passive soft magnetic propagating elements and the magnetoresistive bubble detectors of rf-sputtered permalloy thin films, are fabricated by photolithography. The geometrical requirements for the definition of lines and gaps in a bubble memory device well exceed those in conventional semiconductor technology and get close to the resolution limits of optical lithography.

We have completed the topological lay-out design of bubble memory microcircuitry masks for a 32 Kbit memory device on 5 μm bubble materials as well as for a 64 Kbit and a 256 Kbit device on 3 μm bubble

materials by using the computer aided design software system developed in our Institute. The 32 Kbit and 64 Kbit mask-sets have been produced in Hungary in cooperation with the Research Institute for Electronics, Budapest, and are at our disposal for bubble memory wafer processing.

By applying the technological processes described above several hundred bubble memory chips of 32 Kbit capacity have been fabricated and tested on wafers. The equipment used in this test has been developed and built in the Institute. The selected operating chips have been prepared for packaging and several samples of packaged bubble memory devices have been completed and evaluated in a CAMAC based intelligent test station with encouraging results. There has been a constant interaction between people working on the optimization of the fabrication processes and those testing and qualifying the products.

Preliminary fabrication experiments with small-size test chips on 3 μm bubble materials show promising results for the production of 64 Kbit bubble memory chips in the near future.

PUBLICATIONS: 89, 109, 262, 263, 264, 303, 326

RESEARCH INTO OPTICAL MEMORIES AND COHERENT OPTICS

Gy. Bencze, Gy. Eisler, A. Hámori, G. Kiss, L.V. Kriveczky, Gy. Nagy, P. Varga, Vu duy Phu, Cs. Zakar

Optical memories and coherent optics represent an important area of research and a great deal of work has been done in cooperation with the Lebedev Physical Institute, Moscow, USSR.

(a) A new input device for holographic memories

The crucial point of holographic memories nowadays is to find proper materials and methods for the page composer. For this purpose the ceramic material (Pb $La_xZr_{0.65}Ti_{0.35}O_3$) was investigated. When x=8% the ceramic material is hard in the ferroelectric sense and it is suitable for constructing 2D page composers, but due to remanence effects the average writing speed with this material was shown to be insufficient. High speed and appreciable contrast is offered by soft (x=10-12%) PLZT. A 1D page composer consisting of 128 cells was constructed on a PLZT wafer, the distance between the 10 mm x 0.2 mm electrode bars was 0.2 mm; for switching of the gates, a transverse electric field was applied. The transmission of a pair of pulses of 4 μs width and 10 μs delay is shown in *Fig. 1*. The figure of merit for a page composer is the contrast of the

transfer, i.e. the ratio between the light transmission of an open gate and that of a closed gate which transmits a small amount of light due to the influence of the electric pulses connected to the electrodes near by. The contrast vs. pulse height voltage is plotted in *Fig. 2*.

Soft PLZT has proved to be a suitable material for 1D page composers, in view of which the preparation of wafers containing 256 gates seems to be realizable.

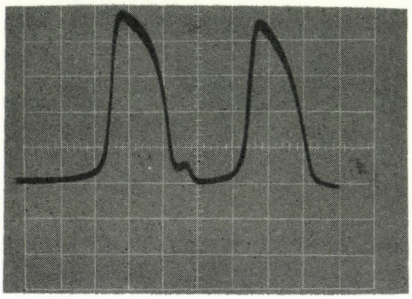

Fig. 1

Pair of light pulses, transmitted by a single gate

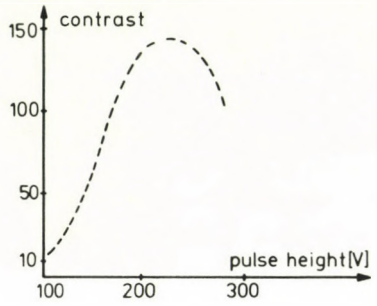

Fig. 2

Contrast transfer of soft PLZT vs. applied pulse voltage

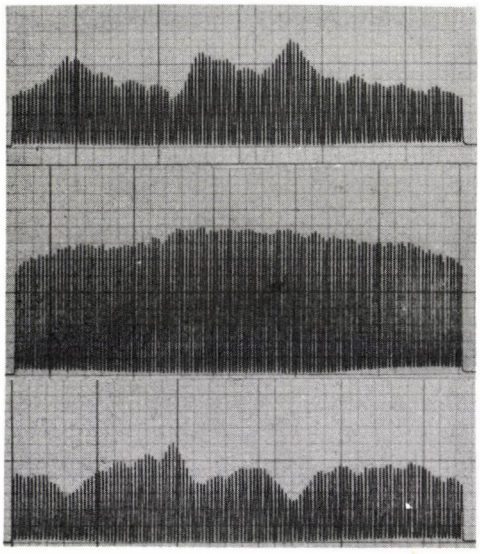

Fig. 3

Reconstructed intensity distribution of a page composer consisting of 128 elements. Positions of the reconstructing beam: -15 µm from the centre; in the centre; +15 µm from the centre

(b) Model experiments for readout of moving holograms

The reconstruction of a Fourier hologram can be performed during its motion since the intensity of the reconstructed image does not depend on the hologram position, thus the reading speed of the continuously moving holograms can be made higher than for steplike motion. The influence of the continuous motion was investigated and no effect was observed. To make clear the details, a diffraction pattern of a 45 µm wide hologram was scanned by a 30 µm wide reconstruction beam. *Figure 3* shows the reconstructed intensity in different positions of the scanning beam. The reference beam was a truncated Gaussian beam therefore the total intensity at the margins

of the pattern is less than in the centre. The ripple of the intensity distribution with an off centre reconstruction beam is due to the aberrations of the Fourier lens, but the distributions measured for symmetric positions of this beam complete themselves thus the time integral of individual signals was constant.

(c) Copying of holograms

Holograms can be copied by a contact procedure in coherent light. The master hologram was registered on an Agfa-Gevaert 8E75 plate, copy was taken on the same film thus good contact could be obtained. Due to the finite thickness of the recording material and the signal and reference beams used for the registration of the master hologram only the O-th and one of the 1-st order diffraction beams appeared in the reconstructed field *(Fig. 4)*. For copying holograms the O-th order plays the role of the reference beam, the 1-st order the role of the signal beam.

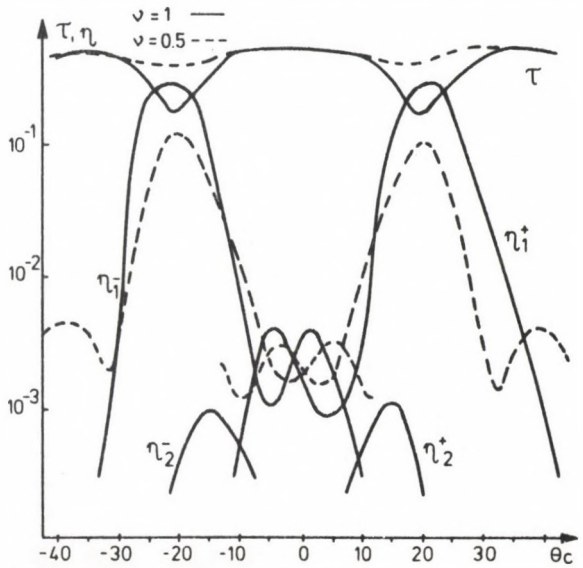

Fig. 4

Efficiency of a phase grating hologram of 122 lines/mm density vs. angle of incidence of the reconstructing beam (θ_c) (τ is the efficiency of the O-th order, η of the higher orders, ν is the modulation depth.)

(d) Development of a device for supervision of the photomasks used in manufacturing integrated circuits

A prototype of a mask supervision system using holographic subtraction is under development in cooperation with the Technical University, Budapest, and the Research Institute for Electronics (HIKI). The resolving power is better than 2 μm, the total field of view realizable in one step is 5x5 mm. The device will be completed in 1981 and will register automatically the number and location of mask imperfections or dust particles.

(e) A digital system for image processing

This system consists of an RV camera having high resolution and linear response, a monitor display, and a small TPA/i computer; the last of these includes an additional microprocessor based hardware arithmetic for increasing the processing speed. The device is used for statistical evaluation of images reconstructed from a holographic memory, i.e. a pattern consisting of black and white squares. By operator's intervention the device selects the domain where the intensity distribution is to be measured then the mean and the rms value can be calculated. A pattern consisting of 1024 squares (each of 256 pixels) is processed within 6 minutes. The shading correction is performed automatically.

(f) Further development of the optical positioning system

The novel elements of the system are the translators NT 125 and NT 150 *(Fig. 5)* which belong to the normal accuracy class. Their basic construction consists of ball bearings which themselves generated the wearing surface. Manual adjustment is possible by means of a micrometer screw. The mean characteristics are:

	NT 125	*NT 150*
Displacement range	*25 mm*	*50 mm*
Scale resolution (depends on the built in micrometer screw)	*2 or 5 µm*	
Reproducibility	*2 µm*	
Max. load	*200 N*	
Weight	*4 N*	*5 N*

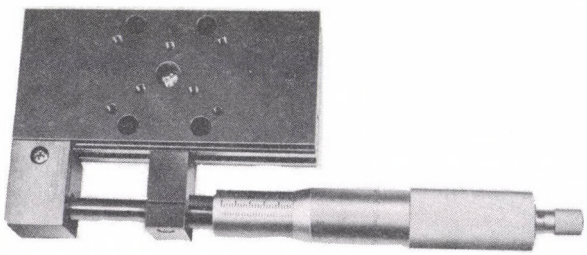

Fig. 5
NT 150 translator

PUBLICATIONS: 37, 193, 335

ION IMPLANTATION AND SEMICONDUCTOR RESEARCH

Mária Ádám, M. Bak, Vera Balatoni-Rudas, J. Balázs*, F. Bánki, F. Bányai, P. Barna, Katalin Benkő, I. Borsos, Gy. Drozdy, P. Fóti, R. Glódi, J. Gyimesi, J. Gyulai, A. Hegedüs, C. Iványi, A. Jávor, P. Keresztes, K. Kertész, L. Királyhidi, Rózsa Kósza*, E. Kótai**, T. Lohner, Á. Majoros, A. Manuaba, G. Mezey, T. Mohácsy, Z. Nyitrai, D. Pacher, F. Pászti, E. Pásztor, G. Pető, L. Pogány, Ágnes Révész, P. Révész, P. Riedl, B. Sallay*, Svetlana Sándor, Vera Schiller, A. Szép, M. Szuhár, A. Téby, P. Tóbiás, G. Vályi*

Registration of end point in plasma etching is important in applications. A simple optical system and method was worked out to solve this problem *(Fig. 6)*.

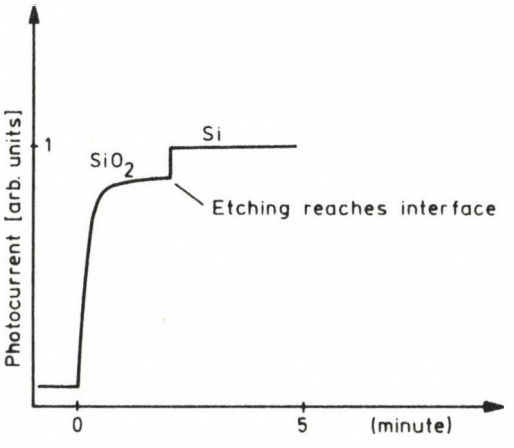

Fig. 6

Registration of end point in plasma etching using λ = 483.5 nm Co line emission

Recently a device technology, based on p-channel enhancement-depletion transistor pairs, has been developed and was demonstrated on a RAM structure. The yields, following the transfer to an industrial research Institute (Research Institute for Electronics, Budapest) were highly successful. This work helped the semiconductor technology line to be kept in "shape".

Results on technology modelling are shown in *Fig. 7*, where an implantation profile is displayed using a program named IMPLAN. This program is part of a simulation program worked out at the Technical University, Budapest, analogous to the SUPREM-II of Stanford University, USA.

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*Tungsram, Budapest
**Research Institute for Electronics (HIKI), Budapest

Simulation of MOS transistors, valid for both enhancement and depletion, is displayed in *Figs. 8* and *9*, where a two-dimensional calculation based on basic equations was performed.

Experiments on laser annealing of semiconductors were mostly focused on recrystallization of amorphous or polycrystalline silicon. The regrowths were of sufficiently high quality to produce devices in thin films. Using a Q-switched laser, operating transistors were fabricated with conventional techniques (p-channel) in regrown films.

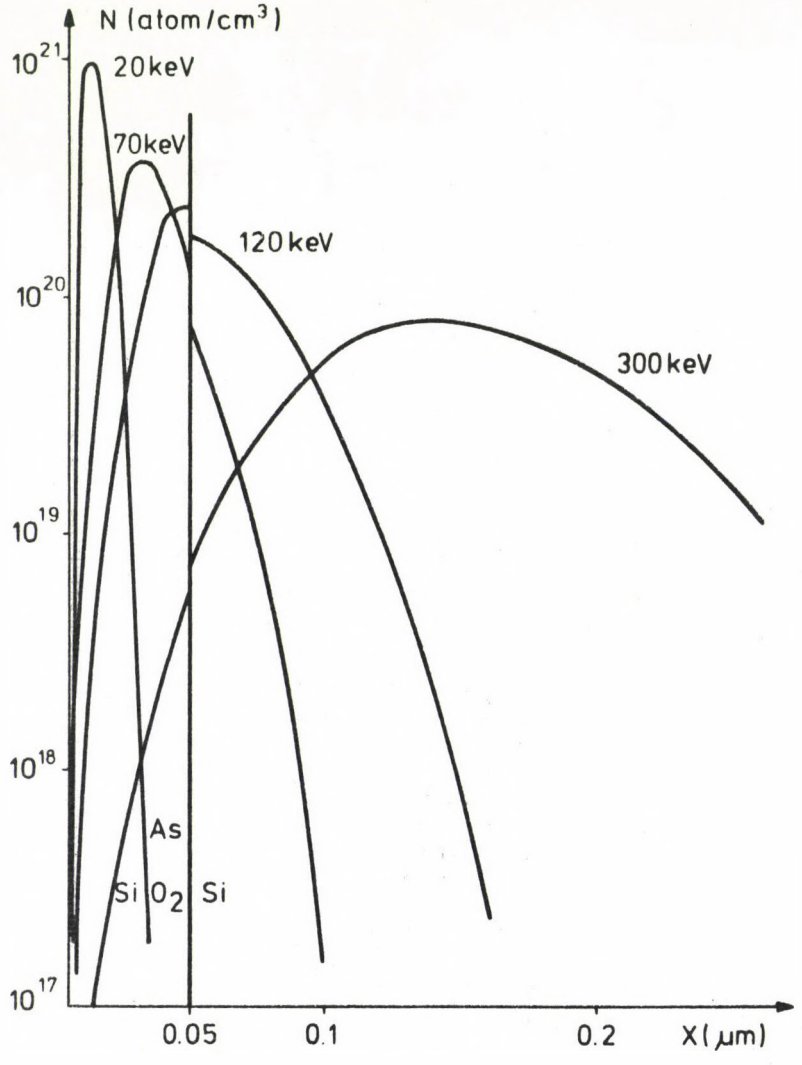
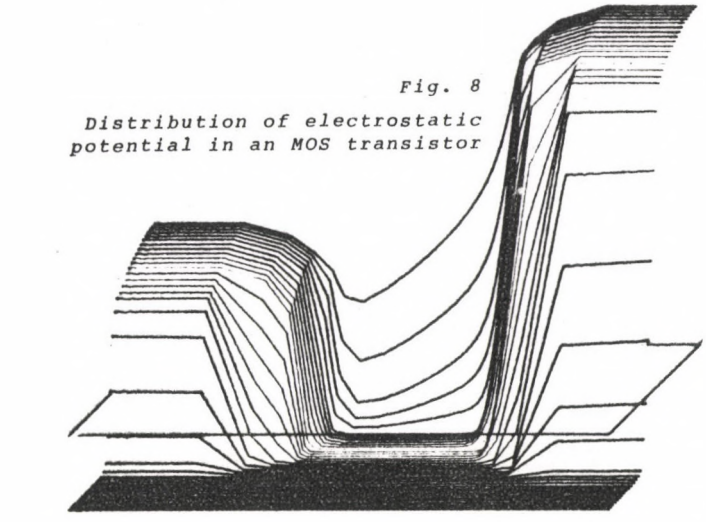


Fig. 7

As-implanted profiles in Si covered by a 0.05 μm thick oxide

Fig. 8

Distribution of electrostatic potential in an MOS transistor



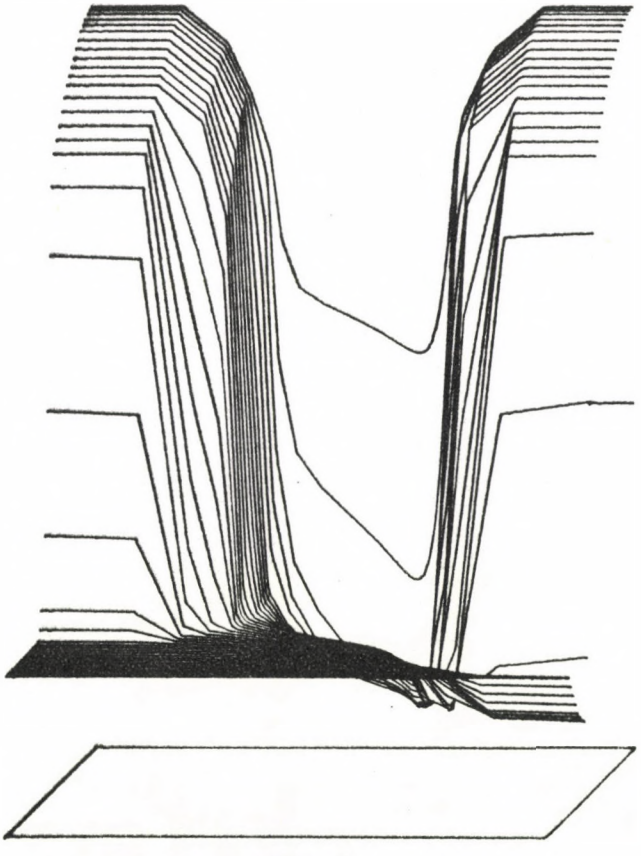


Fig. 9

Distribution of electron concentration in an MOS transistor

Methodological innovations in the fields of nuclear analysis were performed by combining the 3.045 MeV resonance backscattering for oxygen with the glancing angle of incidence technique. Using an angle of 80-83° between incoming beam and target normal, the depth resolution was improved to 6-10 nm compared with the 50 nm for regular geometry. This method contributes to sensitivity also by a factor of about 3.5. In quantitative analysis the contribution of energy straggling has also been taken into account.

Another though not original improvement in our analysis technique was the adaptation of the $^{14}N^{+}$ ion backscattering to detect surface impurities. This technique made possible a check of surface cleanliness for plasma-cleaned silicon and sputtering at tokamak first walls *(Figs. 10* and *11)*.

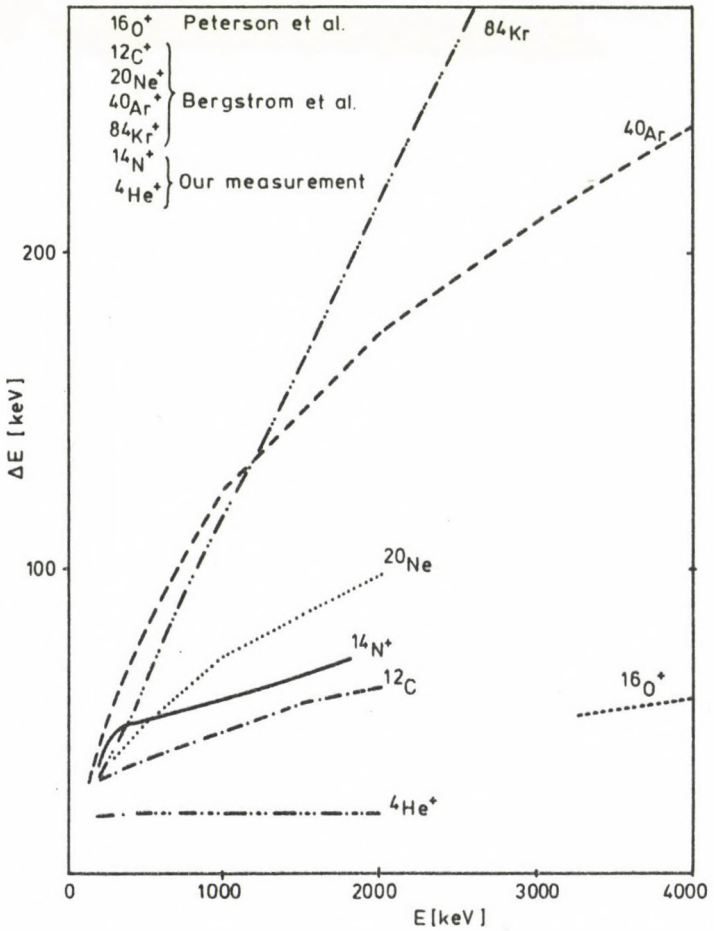


Fig. 10

Energy resolution of surface barrier detector

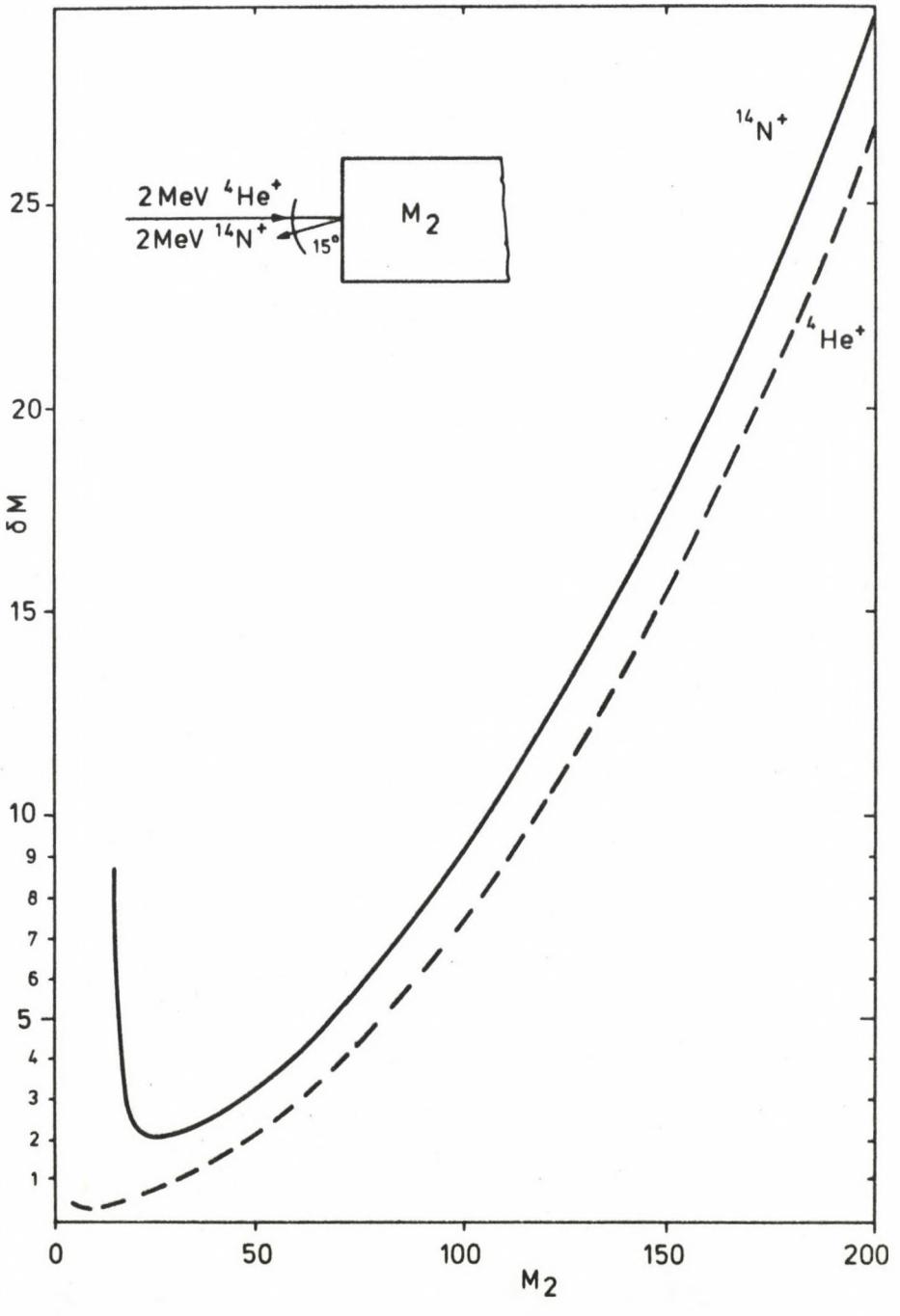


Fig. 11

Mass resolution vs. mass number (M_2) for our backscattering set-up

Sputtering effects were also investigated as a consequence of heavy ion analysis. It has been shown that a $^{14}N^{+}$ beam with MeV energies causes sputtering. An extension of Sigmund's model led to a good fit with experimental results.

Characterization of implanted layers by ellipsometry measurements was another topic. Ellipsometry angle parameters reflect damage distributions after implantation. In order to get reproducible results, care has to be taken of surface cleanliness and the plasma cleaning is also essential.

PUBLICATIONS: 211, 212, 216, 217, 234, 289, 290, 310, 537, 538, 548, 565, 597

AMORPHOUS SEMICONDUCTORS

P. Fazekas, Mária Füstöss-Wégner, J. Gazsó, J. Hajtó, Margit Koós, I. Kósa Somogyi, L. Tóth, G. Zentai

For bulk chalcogenide glasses prepared by the melt/quench procedure, photoluminescence (PL) investigations seem to qualify for the role of the most comprehensive experimental method, since PL, being by its inherent nature a mixture of radiative and non-radiative processes, offers a number of measurable parameters such as characteristics of the excitation and PL spectra, the change in PL intensity with temperature, composition, annealing, its decay kinetics, fatigue during continuous excitation, the effect of doping on these processes, etc. GeS_2 and $GeSe_2$ were subjected to such PL analysis. The results are interpreted as recombination of tightly bound charge pairs in Coulomb centres whose fields are modified by shallow traps.

Thin chalcogenide films were made by vacuum evaporation of the corresponding bulk glasses in powdered form. Transient optical properties and transient photocurrent decay characteristics following pulses of laser illumination were measured and analysed in terms of different theoretical models. A new microscopic model for $GeSe_2$ has been proposed to explain the first step (i.e. a sudden darkening) in the oscillatory period under continuous laser irradiation. The interpretation estimates the disappearance of the low temperature charge order in the system of defects due to the dilution of charged centres by optically induced charged transfer reactions.

Thin films of amorphous hydrogenated silicon, a prospective material for solar cell applications, were prepared by radio frequency glow discharge decomposition of silane (SiH_4) and doping additives. Optical

properties, carrier mobility, density of localized states in the forbidden gap and their dependences on preparation conditions were investigated by the corresponding techniques. Solar cell sandwiches were made and their performances checked on amorphous silicon/metal and on InSe/metal Schottky-barriers.

PUBLICATIONS: 122, 123, 124, 144, 203, 328, 329, 341, 479, 480, 481, 530, 531, 532, 533, 534, 535, 536, 546, 655, 687

ORGANIC CONDUCTORS AND SEMICONDUCTORS

Mária Erő-Gécs, K. Holczer, A. Jánossy, Katalin Kamarás, G. Mihály, L. Mihály, S. Pekker, Katalin Ritvay-Emandity

Powder optical absorption spectra of various tetrathiotetracene (TTT) salts were investigated together with solution spectra of neutral and ionized TTT and TTT dimers. Intramolecular transitions were identified by comparing the solid state and solution spectra. The Coulomb correlation energy corresponding to charge fluctuation to TTT is 0.7 eV, independent of stoichiometry and of solid state properties. Complex TTT salts have a low lying optical excitation due to a transition between ionized and neutral molecules.

The role of disorder and impurities was studied in the highly conducting organic charge transfer salt TTT_2I_3. It was shown that impurities in the conducting TTT chains change the conductivity much more than increased disorder in the iodine chains. In-situ low temperature neutron irradiation measurements indicated that molecular concentrations of defects of the order of 10^{-3} change the low temperature (21 K) resistivity by a factor of 3 and shift the conductivity maximum by more than 100 K. Measurements on crystals containing different amounts of chemical impurities and on $TTTI_{1.5-x}Br_x$ alloys confirmed this picture. These findings are in contradiction with earlier models which emphasized the influence of disordered iodine chains on the electric properties of TTT_2I_3.

Infrared spectra of the TTT salts TTTBr, TTT acetate, $TTTSCN_{0.9}$, TTT_2Cl and several non-stoichiometric phases containing iodine ($TTTI_x$) or mixed halides ($TTTI_xBr_y$) have been studied. In the case of mixed-valence salts, peaks characteristic of both TTT^o and TTT^+ appear. A semi-quantitative estimation regarding average charge transfer could be drawn from the spectra.

The conductivity and 9.1 GHz dielectric constant of neutron irradiated $Qn(TCNQ)_2$ single crystals were found to be strongly affected by defect concentrations of less than 1%. This indicates long range elec-

tronic coherence of the order of 100 lattice constants in the non-irradiated material for which the coherence length may still be impurity limited. It was suggested that a collective excitation of electrons is responsible for the temperature dependence of the large dielectric constant.

Anomalous changes in magnetic and electrical properties indicative of a phase transition at $T_c \approx 220$ K were found in the quasi-one-dimensional complex charge transfer salt N-propyl-quinolinium$(TCNQ)_2$. A series of samples with defects induced by neutron irradiation was investigated. The physical properties above 220 K are little affected by the radiation damage; however, the temperature of the anomaly is shifted to lower temperatures. A dose which is estimated to damage an order of 1% of the molecules lowers T_c from 220 K to 150 K.

The fine structure splitting of the ESR spectrum of N-n-butyl-quinolinium$(TCNQ)_2$ complex salt was measured. The zero-field splitting parameters are: $D = -66.8 \pm 2$ G and $E = 8.3 \pm 1$ G, respectively. The singlet-triplet activation energy is $J = 0.21 \pm 0.01$ eV; the thermic activation energy of exchange measured from line separation and linewidth is in a similar relation to the singlet-triplet excitation energy as found for other 1:2 complexes.

The infrared vibrational spectra of organic quasi-one-dimensional charge transfer salts quinolinium$(TCNQ)_2$ and triethylammonium-$(TCNQ)_2$ were seen to change markedly upon irradiation by high energy neutrons. A reduction of the intensity of some totally symmetric modes and an increase of visibility of other modes were observed in the irradiated samples. The results were discussed in the framework of electron-vibrational interaction theory. The doses required to obtain observable changes are relatively high and point rather to a model of simple electron coupled vibrational modes extended over a few molecules than to phase oscillations of a collective state with a long coherence length.

The so-called breather solution of the sine-Gordon equation was phenomenologically described by an appropriately chosen potential acting between two particles. For some applications the method proved to be equivalent to other classical and quantum calculations.

The dielectric permeability of bound soliton antisoliton pairs was considered. The model yielded an explanation for the anomalously large dielectric constant, the conductivity at microwave frequencies and their low temperature behaviour observed in some quasi-one-dimensional organic charge transfer salts.

The second moment M_2 of the continuous wave NMR spectra of pure and iodine doped polyacetylene was determined. Results were compared with calculations using the structure determined by Baughman et al. The ob-

served M_2 of the *cis* type pure $(CH)_x$ was larger than the theoretical value. The variation of M_2 with iodine doping was consistent with intercalation into planes for an initially *trans* type material. 0.5% iodine doping transformed most of the originally *cis* type of material into *trans* form.

Dc and microwave conductivity and dielectric constant measurements on iodine doped $(CH)_x$ were performed. The gradual variation of the transport properties as a function of the iodine concentration indicated that no sharp phase-transition occurs with increasing doping levels. Charged π-phase kinks localized around I_3^- describe qualitatively the dielectric properties in the lightly doped range.

The dielectric constant of polyacetylene films oriented by rolling was measured. The variation of the dielectric constant and also that of the proton nuclear magnetic resonance lineshape indicate that rolling partially isomerizes cis$(CH)_x$ to trans $(CH)_x$. For oriented trans$(CH)_x$ we found $\varepsilon_{\parallel}=5.7$ and $\varepsilon_{\perp}=4.0$ in the plane of the film. A calculation based on bond polarizabilities led to qualitative agreement with experiment.

PUBLICATIONS: 103, 104, 105, 152, 153, 154, 178, 179, 180, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 293, 304, 435, 504, 516, 571, 572, 573, 575, 576, 580

LIQUID CRYSTAL RESEARCH

L. Bata, Ágnes Buka, N. Éber, I. Jánossy, Katalin Pintér, I. Pócsik, L. Siklós, J. Szabon

A method for determining impurity content by DSC was applied to liquid crystalline compounds. Corrections due to thermal resistance and thermal capacity need to be taken into consideration. With these corrections the method is suitable for the quantitative characterization of very low impurity contents contaminating liquid crystalline compounds.

Dielectric permittivities were measured on compounds having different smectic phases in broad temperature intervals. Both the parallel and the perpendicular component of permittivity were given and the variations were interpreted. The intensity of the low frequency dielectric dispersion was interpreted by Bordewijk's formula and dipole-dipole correlation. The temperature dependences of the relaxation time in the different liquid crystalline phases were given. A small break was found at the N-SmA, SmA-SmC, SmB-SmF phase transitions, an order of magnitude change at the SmA-SmB and SmC-SmB phase transition, and a definite step at the SmF-SmG phase transition. The big change at these last three phase

transitions was interpreted by the appearance of the collective librational modes.

Light scattering measurements have caused doubts as to whether the Maier-Saupe theory of nematic liquid crystals is correct. It has been shown that if an averaging process is supposed the measurements are in agreement with the theory. An idea has been presented concerning the possibility of an error in the commonly accepted picture of the nematic phase.

It has been shown that shear flow destabilizes the planar texture of cholesterics of pitch small compared with sample thickness above a threshold shear rate, and that in the presence of the shear, perturbations of the planar configuration propagate with a velocity proportional to the shear rate. A simplified theory of these effects has been presented and compared with the experimental data.

PUBLICATIONS: 62, 63, 64, 96, 164, 185, 374, 400, 421, 505, 547, 609

RESEARCH ON METAL PHYSICS

I. Bakonyi, Éva Császár-Gilicze, Gy. Faigel, L. Gránásy, C. Hargitai, T. Kemény, Éva Kisdi-Koszó, G. Konczos, A. Lovas, G. Mészáros, I. Nagy, A. Sütő, Erzsébet Svab, J. Takács, L. Takács, T. Tarnóczi, K. Tompa, J. Tóth, Enikő Tóth-Kádár, Katalin Vajsz-Jámbor, B. Vasvári, I. Vincze, Katalin Zámbó-Balla

During the years 1979 and 1980 our research activities relating to metallic glasses and metal-gas reactions were continued.

For the preparation of metallic glass ribbons a new apparatus equipped with a water cooled quenching disk and a vacuum chamber was designed and constructed. The effects of the quenching conditions on the physical and chemical properties of glassy ribbons have been systematically investigated.

The influence of the melt superheat on the microhardness, HV, and the coercive force, H_c, of iron-boron glassy alloys was studied. The subsequent low temperature annealing does not eliminate the differences in HV; however, a definite convergence of H_c was observed. The changes in HV are different for the hypo- and hypereutectic concentration ranges.

We have investigated the correlation between the cooling rate or the melt superheat and the induced magnetic anisotropy of rapidly quenched glassy iron-boron alloys. In samples with 15 at% boron concentration only a very small induced anisotropy could be achieved and it was practically independent of the technological parameters. At higher boron concentra-

tions, both cooling rate and melt superheats influenced the induced magnetic anisotropy.

Correlation was found between the various technological parameters such as cooling rate and melt temperature, and the magnetic after-effect in glassy iron-boron alloys. The magnetic after-effect may be a measure of the mobility of boron atoms in amorphous Fe-B alloys.

The influence of casting conditions on the thermal properties of $Fe_{83.4}B_{16.6}$ metallic glass has been investigated by differential scanning calorimetry (DSC). The differences in the glassy state of the samples produced under different conditions were followed through the changes in their crystallization process, measuring its heat release, starting temperature and kinetics. It has been found that the starting temperature and the crystallization kinetics are sensitive to the cooling rate.

The electrochemical corrosion of $Fe_{100-x}B_x$ (x = 11.7-21.6) metallic glasses was studied by the potentiostatic method. The corrosion current was determined from the anodic and cathodic polarization curves. It was found that the corrosion current varied with the quenching rate and was also influenced by the boron content in the range investigated. The rate of corrosion was also different on the two sides of the as-quenched specimens.

$Fe_{17}Ni_{63.8}B_{19.2}$ and $Fe_{31.5}Ni_{49.2}B_{12.3}Si_7$ metallic glasses were investigated by Auger electron spectroscopy (AES) measuring the in-plane and in-depth distribution of the different components on both sides of the ribbons. The results show a Ni-enrichment and a reduction of the boron content at the samples. The depth of the inhomogeneous regions is about 100 nm and the variation of the concentration within the ribbons was found to be less than 1 at% for all components. In some cases near the surface a peculiar quasiperiodic concentration fluctuation was detected in the relaxed sample.

The structure of the electroless deposited Ni-P alloys and the melt-quenched Fe-B glassy alloys was determined by high-angle X-ray diffraction measurements using MoK radiation. In both cases, our results show that as to the first three coordination shells, the short range order changes smoothly from the pure transition metal up to around 25 at% metalloid content.

X-ray and neutron diffraction experiments were carried out on two samples of splat cooled $Ni_{60}Nb_{40}$ metallic glass containing natural Ni and ^{58}Ni isotope, respectively. All the three structure factors $S_{NiNi}(Q)$, $S_{NiNb}(Q)$ and $S_{NbNb}(Q)$ were calculated from the diffraction data. The total and partial distribution functions have been determined.

Iron hyperfine-field distributions of amorphous iron-boron (15-25 at% B) alloys were determined by the Mössbauer technique. They

show the presence of a strongly correlated local order which can be described in the $Fe_{75}B_{25}$ glass as the chemical short-range order of the Fe_3B intermetallic compound. The measured hyperfine fields at iron sites in Fe-B glassy alloys were compared with the calculations based on two models. The first model is based on the dense random packing of spheres; the second emphasizes the short-range order formed in crystalline materials with similar compositions. The crystalline short-range order is found to give a better fit and suggests specific improvements in the concepts used to understand the atomic structure of glasses.

Our Mössbauer investigations on melt quenched $(Fe_{1-x}Ni_x)_{75}B_{25}$ ($0 \leq x \leq 0.75$) glasses have shown a change in the geometrical arrangement of near neighbours closely following that of the crystalline counterparts (Fe_3B is tetragonal, Ni_3B is orthorhombic). The distribution of transition metal atoms is not random at high Ni concentrations: Ni atoms prefer a neighbourhood with a higher boron coordination. The chemical short-range order of sputtered amorphous $Fe_{1-x}B_x$ ($0.09 \leq x \leq 0.30$) alloys characterized via the ^{57}Fe hyperfine field distribution is very similar to that of liquid quenched samples.

We have compared the local orders of dense random packing, random packing of molecular units and quasi crystalline models. The polyhedra found by the nearest neighbours of the metalloid atoms in a two component Bennett structure are compared with the Bernal holes and the predictions of more ordered models. Trigonal prisms are shown to be the most frequent polyhedra for coordination numbers from 6 to 9.

The electrical resistance and the thermopower of the Fe-B, Fe-B-Si, Fe-Co-B, Fe-Ni-B and $Fe_{80}TM_3B_{17}$ amorphous systems (TM is one of the 3d, 4d or 5d transition metals) have been measured from room temperature to the amorphous-crystalline transformation. The extended Ziman theory for the electrical transport properties of structurally disordered systems was modified and was used to interpret some of the experimental data.

A formalism was developed to calculate the local density of states in a structural metal using the mathematical methods of band structure calculations of crystalline materials. Remaining consistently in the direct space throughout the whole calculation, a considerable simplification occurs due to the isotropy of the systems involved. Preliminary results for amorphous iron were obtained.

The results of magnetic and Mössbauer measurements on 3d transition metal-light metalloid intermetallic compounds and metallic glasses have been discussed on the basis of the donor model. This model can predict the maximum possible value of the magnetic moment up to 50 at% metalloid concentration. The localization of electronic states with increasing metalloid has also been shown.

We have shown that structural disorder has minor effects on the shape of the magnetization curve, on the magnetic moments, and on the Curie temperatures. We have measured the specific heat, c_p, and the electrical resistivity around the Curie temperature in five Ni-Fe based metallic glasses. Well-defined c_p anomalies were observed in $Fe_{20}Ni_{60}B_{20}$ and $Fe_{30}Ni_{50}B_{20}$ alloys. The temperature coefficients of resistivity exhibit well-defined anomalies near T_c similarly to the crystalline metallic ferromagnets.

The magnetic after-effect in amorphous $Fe_{100-x}B_x$ ($13 \leq x \leq 24$) alloys has been investigated. It has been shown that the ordering of boron atoms plays an important role. The boron atoms in iron-boron metallic glasses seem to have maximum mobility at the eutectic concentration. The effects of annealing in a magnetic field or under applied stress on magnetic anisotropy of amorphous Fe-B alloys have also been studied. The uniaxial anisotropy dependence on boron concentration again suggests the role of boron ordering in these alloys. Magnetostriction was measured using the opto-mechanical method which gave the possibility to study the magnetostriction on quasi-free samples. Investigations were carried out to determine the effects of various heat treatments (stress-relief, magnetic annealing and annealing under tensile stress) on the saturation magnetostriction of iron-boron amorphous alloys.

Results were obtained from a series of aging heat treatments carried out at different temperatures for 10^4 hours. Static coercive force, H_c, and microhardness, HV, measurements were done during the heat treatment. H_c and HV do not change monotonously during the aging thereby showing that stresses can arise from the atomic regrouping. After long-term aging, the formation of holes was observed even though the specimens remained X-ray amorphous.

Thermomagnetic, thermopower (S) and X-ray and electron diffraction measurements were made on rapidly quenched $Fe_{100-x}B_x$ ($11.7 \leq x \leq 24.5$) after different heat treatments. For local measurements of S around room temperature a simple surface probe "thermotester" has been designed. The thermopower of amorphous Fe-B alloys measured above room temperature is negative and depends slightly on the boron content, on the temperature and on the relaxation process. The change in S, measured around 300 K after having crystallized the sample, is positive in the hypo- and negative in the hypereutectic range corresponding to the acutal structure and the fraction of phase compounds (Fe, Fe_3B and Fe_2B). X-ray and electron diffractograms clearly indicate an extra stability of metastable Fe_3B around 20 at% boron.

The static coercive force, saturation magnetization at room temperature and the temperature dependence of magnetization have been

measured on the $Fe_{80}TM_3B_{17}$ quasi-eutectic amorphous alloys (TM = 3d, 4d, 5d transition metals). The influence of TM on saturation magnetization shows typical group-number effect. H_c of the as-quenched ribbons decreases with TM additives but it also depends on the temperature of the melt.

The influence of 3d, 4d and 5d transition metal additives on the stability of $Fe_{80}TM_3B_{17}$ quasi-eutectic metallic glasses has been investigated by calorimetry. The third component from the 4th or 5th rows yields more frequently the occurrence of double stage crystallization than that from the 3rd row. A tendency is observed that the energy of crystallization and the temperature coefficient of resistivity decrease with increasing crystallization temperature.

The crystallization of $(Fe_{1-x}\ TM_x)_{75+y}B_{25-y}$ (TM = Co and Ni) glasses was investigated in the $0 \leq x < 1$, $0 \leq y \leq 10$ composition range by calorimetry, X-ray diffraction and Mössbauer spectroscopy. The crystalline phases were identified and their relation to possible changes in the chemical short-range order of these amorphous alloys was discussed.

We continued our work on the kinetics of metal-gas reactions. The carburization and decarburization rate of polycrystalline iron-nickel alloys have been determined by a new resistivity relaxation measuring system. The measurements were carried out in CH_4-H_2 mixtures between 900 and 1100 ^{o}C. It may be stated that the rate of decarburization in dry hydrogen is higher on fcc iron-nickel alloys than on pure iron at the same temperature and that it increases at higher nickel concentrations by more than an order of magnitude. The rate of carburization is also accelerated by the presence of nickel in the alloy.

Measurements of thermopower during the ferrite-austenite transition have been performed too. A scheme for calculating the surface carburization and decarburization rate constants and the diffusion constant of carbon in iron has been elaborated which uses the results of the above measurements.

PUBLICATIONS: 116, 167, 182, 183, 184, 190, 191, 219, 220, 254, 258, 259, 279, 282, 283, 312, 313, 323, 325, 344, 345, 346, 373, 382, 383, 385, 386, 387, 388, 389, 390, 394, 395, 396, 397, 432, 433, 445, 447, 466, 466a, 473, 474, 475, 476, 485, 518, 519, 520, 521, 524, 525, 544, 545, 551, 552, 553, 563, 583, 586, 587, 610, 611, 617, 618, 626, 627, 628, 629, 640, 641, 642, 643, 647, 648, 649, 650, 651, 652, 659, 660, 663, 664, 665, 672, 675, 676, 677, 678, 679, 680

TECHNICAL DEVELOPMENT

ELECTRONIC MEASURING EQUIPMENT

O. Bakos, L. Farkas, P. Horváth, B. Lévay, I. Pálmai, P. Szőke, F. Tóth

The highly diverse research in physics and in chemistry within the Institute has meant a great deal of activity in developing and updating various instruments and measuring units. Our work has mainly centred around the following:

- Transient recorders,
- Power supplies for lasers,
- Power supplies for magnets and solenoids,
- Temperature controllers,
- Fabry-Perot interferometer stabilizers,
- Automatic control units for Chochralski pullers,
- Moisture testers,
- NMR marginal oscillator,
- Digital clocks,
- Box-car integrator,
- Single phase lock-in amplifiers,
- Two phase lock-in amplifiers,
- Logarithmic amplifiers,
- Vapour content tester,
- Fast resistor meter.

Our activities have also extended to orders from outside the Institute and we are also engaged in servicing a wide range of measuring equipment.

PUBLICATIONS: 98, 443

LOW TEMPERATURE MEASUREMENT TECHNIQUES

J. Balla, B. Fonyó, A. Pintér, I. Szakáll

The field covered by low temperature measuring techniques has necessitated the designing and constructing of variable gas-flow cooling systems for

- optical measuring between 4.2 and 300K,
- ESR measurements between 4.5 and 300K,
- Hall effect measurements between 4.2 and 600K,

- magnetic measuring between 4.2 and 450K,
- Mössbauer effect measurements in strong magnetic fields between 4.2 and 400K,
- NMR measurements between 77 and 800K,
- measuring the magnetic properties of thin layers between 80 and 450K,
- measuring the electric parameters of microelectronic semiconductor parts between 80 and 850K.

In addition, the overall production of liquid coolants and technical gases amounted to:

2,500 ℓ liquid helium,
450,000 ℓ liquid nitrogen,
7,300 m^3 dry nitrogen gas.

HOLLOW CATHODE LASER RESEARCH

L. Csillag, M. Jánossy, Le trong Muu, K. Rózsa

Our research work in the recent past has been concerned with the technical development and with the scientific problems of hollow cathode gas lasers. Experiments were performed mainly on the He-Kr noble gas mixture and the Ne-Al cathode sputtering operated laser systems. The construction of the lasers was such that the discharge was divided into several parts by using separate cathodes; in this way the arcing threshold current could be considerably increased. In the He-Kr system operating at the 469.4 nm blue line of the Kr ion the measurements were aimed at determining the optimum geometry and gas filling for the laser. It was found that the lowest threshold current for laser oscillation occurs in the 10-12 torr He pressure range, but output power increases more strongly at high He pressures around 30 torr. In this region 75 mW power output was obtained from a tube of 40 cm active length having six internal anode rods. By exciting the discharge in a quasi cw manner by 100 μs halfwidth and 20 A peak current pulses we obtained a power output which rose to 450 mW.

It was shown that the excitation mechanism of the Kr ion laser transition is different from that assumed up to now.

The calculations showed in the hollow cathode discharge the Kr ions are produced mainly by electron collisions and not by Penning collisions with He metastable atoms, as is the case in pulsed positive column discharges. This explains why the high voltage hollow cathode system increases output power and decreases threshold current of this laser more than expected; namely, the increased number of high energy electrons in this discharge produces a larger density of Kr ions.

Laser operation at the 704.2 nm transition of Al II was investigated in a Ne-Al hollow cathode discharge where the Al vapour was produced by cathode sputtering. It was found that a relatively low threshold current occurs (4.9 A) in a large 8.5 mm internal diameter tube with three internal anode rods. Optimum Ne pressure was found to be 1 torr, which

agrees quite well with the value where optimum Ne ion density occurs in the discharge. This supports the charge transfer excitation mechanism where Ne ions are dominant for this laser transition.

PUBLICATIONS: 48, 76, 294, 295, 506, 507, 614, 615

LASER SYSTEMS FOR INDUSTRIAL USE

I. Czigány, A. Czitrovszky, P. Jani, I. Kertész, Á. Kiss, P. Schmidt

Our main concern has been the fulfilment of obligations based on our contracts with the State Office for Technical Development. These activities of ours can be divided into two principal areas:

- interferometric measurement systems;
- laser material processing systems.

During the creation of the interferometric measurement system under generally formulated measurement needs of previous years (length-, angle-, straightness measurement, etc.) we came across the concrete measurement problems of the machine tool manufacturing industry for gauging the ball-bearing spindles. The system constructed satisfies the following user defined specifications:

- maximum measuring velocity 40 cm/s;
- 1 part in 10^7 absolute accuracy in the automatic ambient parameter measuring mode of operation;
- length measurement, velocity measurement;
- measurement of linearity of displacement under external command.

The operation of the system is commanded by a microprocessor. The main considerations during development were:

- programmed data processing depending on the mode of operation;
- provision for the enlargement of the basic system for flatness measurement, multiaxis measurement, vibration analysis;
- simple, dependable, well arranged handling.

The data processing system handles several user defined peripheral devices, e.g. X-Y writer, teletype, thermoprinter, accepts some command signal and handles them in a preprogrammed way.

The material processing system is based on an A-O Q-switched Nd-YAG laser the peak power of which is 5-10 kW in the TEMoo mode with a τ_{FWHM} 100 µs and at repetition rate of 1-5 kHz. The following basic processing methods were developed:

- resistance trimming, engraving techniques;
- scribing on silicon substrates;
- laser annealing of ion-implanted silicon substrates.

The scribing techniques resulted in obtaining a slot width of 20-30 μm and a depth of 150 μm on a 300 μm thick substrate which permitted the reliable breaking of the materials. The first laser annealed MOS transistors on isolator substrates were produced in collaboration with the ion implantation group of the Institute. The last two years saw the finalization of a prototype laser processing laboratory with the aim of providing the industry facilities for individual processing needs such as the trial of know-how.

The laser equipment of the pilot laboratory are the following.

- Nd:glass pulse laser for the drilling of small diameters in hard materials (tungsten, diamond, etc.) 10-100 μm;
- 300 W cw CO_2 laser for cutting and drilling techniques;
- the system based on the Nd:YAG laser.

In collaboration with the Lebedev Physical Institute, Moscow, we developed an A-O Q-switched Nd:YAG laser which, by way of frequency conversion to 2ω, emits a green line. The active material placed in the resonator was $Ba_2Na(NbO_3)_5$, the so called banan crystal.

The construction permitted a 100% power conversion. The theoretical dependences of the signal at 2ω on the pumping power were studied.

PUBLICATIONS: 80, 434

INSTABILITY OF OPTICAL MULTILAYER FILTERS

P. Apai, A. Lutter

Interference filters suitable for different optical analytical systems were prepared using experience gained from light scattering measurements.

In such work the stability of the filters is a critical problem so we studied the change of the spectral characteristics of filters caused by atmospheric and thermal effects.

Figure 1 shows the dependence of the peak wavelength of an interference filter on heating and cooling. The changes are basically reversible. The shift in the peak wavelength of the filter is primarily determined by the packing density of the spacer layer; the refraction index of layers with higher packing density is less sensitive to the temperature change. This effect is mainly due to the water absorption of

the layer. A close correlation was experimentally found between the wavelength shift and the packing density of the spacer layer of the filters.

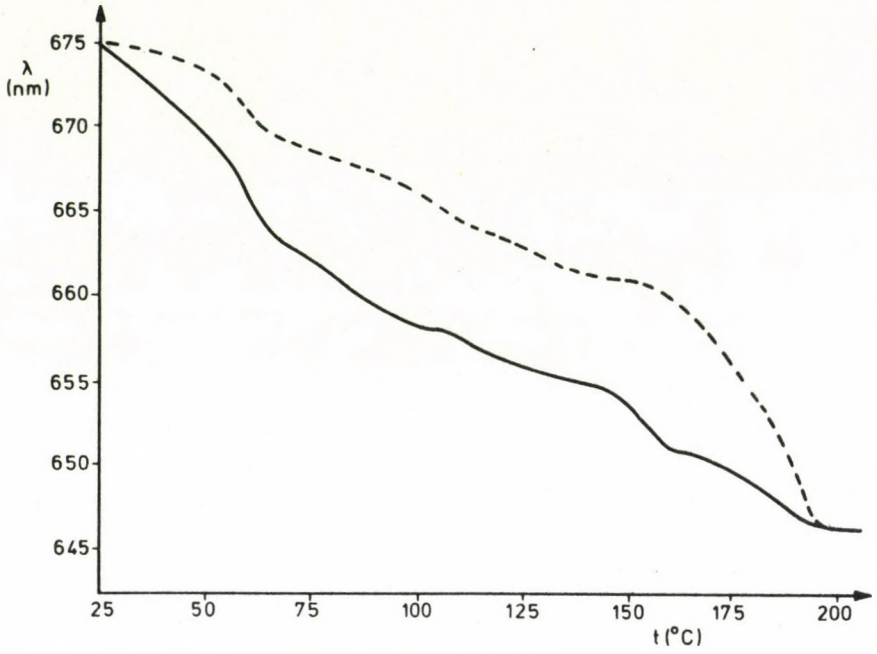


Fig. 1

Typical change of peak wavelength of filters as a function of temperature. Solid line: cooling the sample; broken line: heating the sample

The stability measurements can be used for examining the packing densities and measuring the diameter distribution of the pores as well.

Table I

REFRACTION INDICES (n) AND PACKING DENSITIES (α) OF DIFFERENT DIELECTRIC FILTER COMPONENTS

Film material	n_{25^oC}	n_{300^oC}	α
MgF_2	1.38	1.30	0.77
ZnS	2.31	2.30	0.99
SiO_x	1.52	1.42	0.75
SiO_x	1.57	1.52	0.89
ZrO_2	2.00	1.94	0.90

Table I shows the change of the refraction indices under heating and the packing densities of different dielectric filter components. Only the ZnS films were stable under heating; the change in the refraction indices of the other components depends on the evaporation parameters.

PUBLICATION: 557

LABORATORY FOR OPTICAL SPECTROSCOPY

J. Szőke, J. Tóth

The main part of our development and automatization work was devoted to the instrumentation of electronic (absorption and luminescence) spectroscopy. During the last two years numerous papers have been published in which the conceptions of instrumentation problems were discussed. In view of this, the luminescence spectrometers, grating monochromators, and computer compatible interfacing of conventional analog instruments were evaluated. A new pulsed computer controlled nanosecond luminescence/Raman spectrometer is now under actual development.

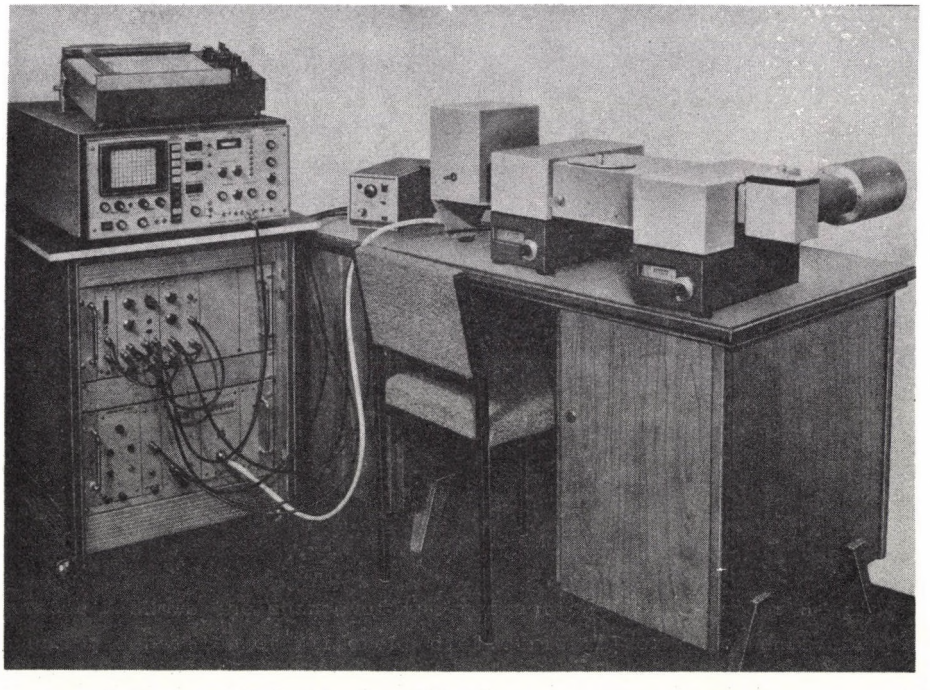


Fig. 2

Nanosecond decay time meter and time resolution spectrometer

The development of our nanosecond decay time meter built in 1978 had been continued and by building in a second monochromator the measurement of time resolved spectra also became possible. A similar instrument with polarizers in the sample chamber was built in collaboration with the Biophysical Institute of the Medical University, Debrecen, by using Zeiss SPM-2 monochromators *(Fig. 2)*. In the course of this work a new nanosecond flashlamp was developed with interchangeable gas filling and a maximum repetition rate of 50 kHz.

The automation level of our SPECORD UV-VIS spectrophotometer was increased by a digitally controlled scanning mechanism and a dual slope DIGITIZER and PAPER TAPE CONTROL system. Similar works were performed on the spectrophotometer (Perkin Elmer Model 340) UV of the Institute for Biophysics of the Semmelweiss Medical University, on the Raman spectrometer and on the circular dichroism spectrometer of Eötvös Loránd University.

A new stabilized xenon lamp supply *(Fig. 3)* has been developed for our laboratory-made spectroluminometer having one meter grating monochromators. UV crystal polarizers and He cryostat were also incorporated for measuring the vibronic fine structure of the electronic spectra.

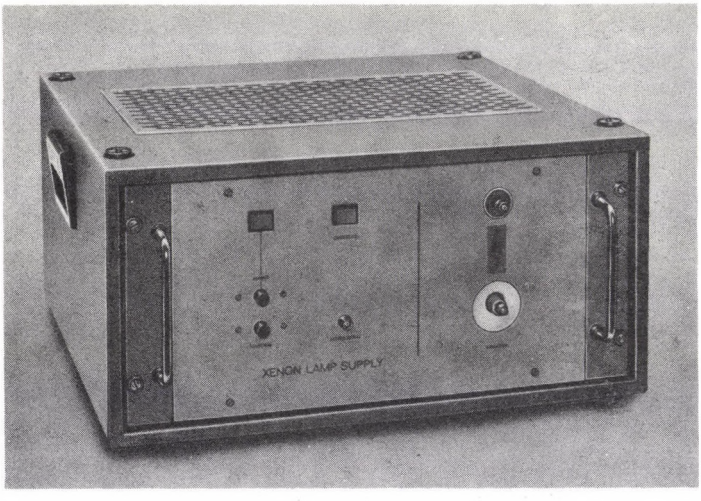


Fig. 3
150 W Xe lamp stabilized supply

In the course of the computerized data processing of spectroscopic measurements, programs were written by using orthogonal (Gram) polynomials for the fitting and differentiation of non-linear functions and for the elimination of instrumental noise from the experimental spectra.

Numerous papers were devoted to the evaluation methods of the nanosecond decay curves. The programs for simulation and fitting were written in FOKAL language for a TPA/i small computer.

The quantum theoretical investigation of the molecular electronic absorption and luminescence spectra has also been continually surveyed and published.

PUBLICATIONS: 321, 322, 323, 324, 638, 653

NEUTRON SPECTROSCOPY

L. Cser, N. Kroó, F. Mezei, L. Rosta, Erzsébet Svéb, I. Vizi, Gy. Zsigmond

Neutron diffraction structure studies were performed on amorphous alloys (Ni-Nb, Cu-Zr, Fe-B prepared by rapid quenching from the melt) at the WWR-SM reactor of the Institute. Combined neutron and X-ray diffraction measurements were carried out on two $Ni_{60}Nb_{40}$ metallic glass samples containing natural Ni and ^{58}Ni isotope respectively. From the structure factors obtained after correction and normalization of the measured spectra the partial structure factors were separated for the three kinds of atomic pairs: Ni-Ni, Ni-Nb and Nb-Nb *(Fig. 4)*. By means of Fourier

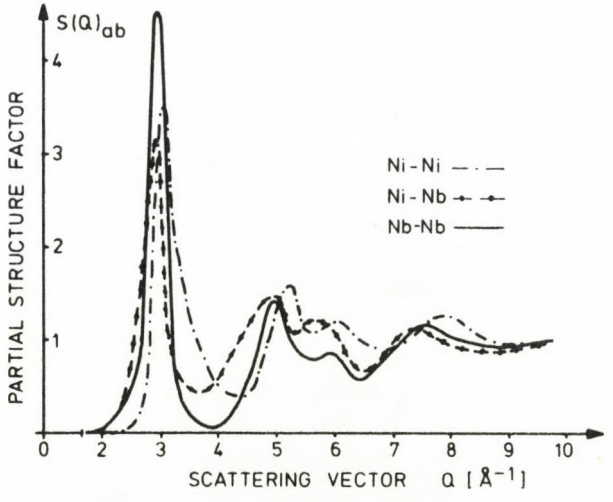


Fig. 4

Partial structure factors for Ni-Ni, Ni-Nb, and Nb-Nb atomic pairs in $Ni_{60}Nb_{40}$ metallic glass

transformation the partial distribution functions characterizing the local coordinations were obtained *(Fig. 5)*. The atomic distances were obtained as follows: r_{Ni-Ni} = 2.52 Å, r_{Ni-Nb} = 2.72 Å and r_{Nb-Nb} = 2.70 Å; the values for the number of nearest neighbours being n_{Ni-Ni} = 7.3, n_{Ni-Nb} = 4.5, n_{Nb-Ni} = 6.8 and n_{Nb-Nb} = 5.4.

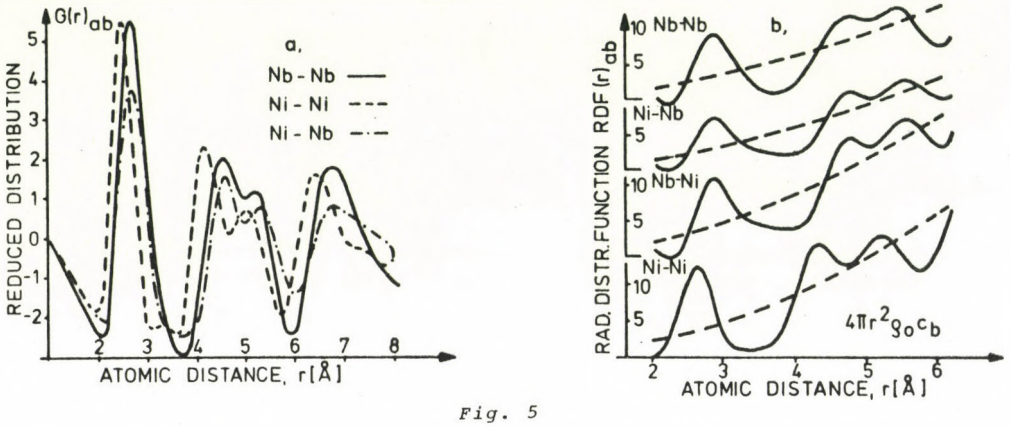


Fig. 5

Partial distribution functions for the Ni-Ni, Ni-Nb and Nb-Nb atomic pairs in $Ni_{60}Nb_{40}$ metallic glass.
a) reduced distribution function
b) radial distribution function

The previous neutron diffraction studies on magnetic structure and phase transition in substituted orthoferrites carried out on powder samples were extended to the investigation of single crystals. The $ErFe_{0.99}Co_{0.005}Ti_{0.005}O_3$ and $ErFe_{1-x}Mn_xO_3$ (x = 0.1, 0.2, 0.3) single crystals were oriented in the [1$\bar{1}$1] zone axis and the (110), (011), ($\bar{1}$01), ($\bar{2}$02) reflections were measured. The Rocking-curve of the Bragg reflections showed some of the crystals to consist of slightly disoriented blocks. For the $ErFe_{0.8}Mn_{0.2}O_3$ and $ErFe_{0.7}Mn_{0.3}O_3$ samples the temperature dependence of the (110) magnetic reflection was measured in the 77-400 K temperature range, from which the spin reorientation temperature and the magnetic structure below and above the phase transition were determined.

A small angle scattering device based on the focusing arrangement of two ideal crystals (Ge single crystals of mosaic spread 2') was put into operation at the No.6 thermal neutron channel of the Institute's reactor. This spectrometer gives the possibility to detect microinhomogeneities, dislocation density, magnetic domains, clusters, etc. of the dimension of 1500-5000 Å. The first investigations were performed on Fe-Ni rods as model samples; these rods were mechanically deformed. By means of small

angle neutron scattering we could measure the local density distribution of inhomogeneities caused by deformation along the sample *(Fig. 6)*.

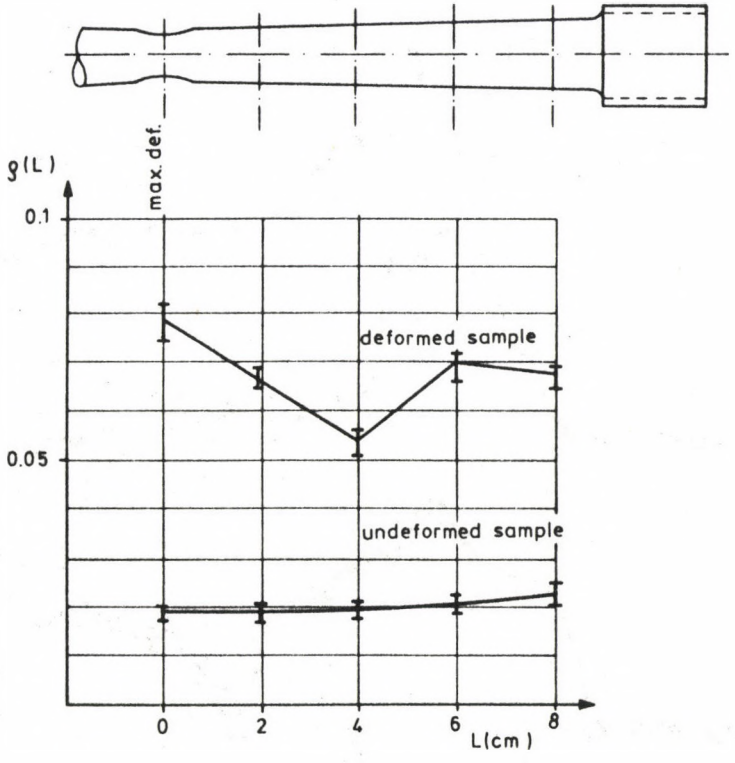


Fig. 6

Density distribution of deformation (ρ) in a Fe-Ni model sample measured by small angle neutron scattering

Using the neutron diffraction technique we studied the structure of nematic liquid crystals and the effect of external magnetic field on the molecular order. Dispersion relations of phonon type collective excitations were also investigated by inelastic neutron scattering. By fast cooling the liquid crystal phase was frozen in. The structure of this glassy state was investigated from diffraction patterns as shown in *Fig. 7*.

A single crystal was prepared from the liquid crystal material para-azoxy-phenetole (PAF) and phonon dispersion curves were determined in two symmetry directions; one of which is shown in *Fig. 8*.

The phonon dispersion curves were also determined in a Cu-Ni system at two different Ni concentrations (5%, 10%) using the inelastic neutron diffraction method.

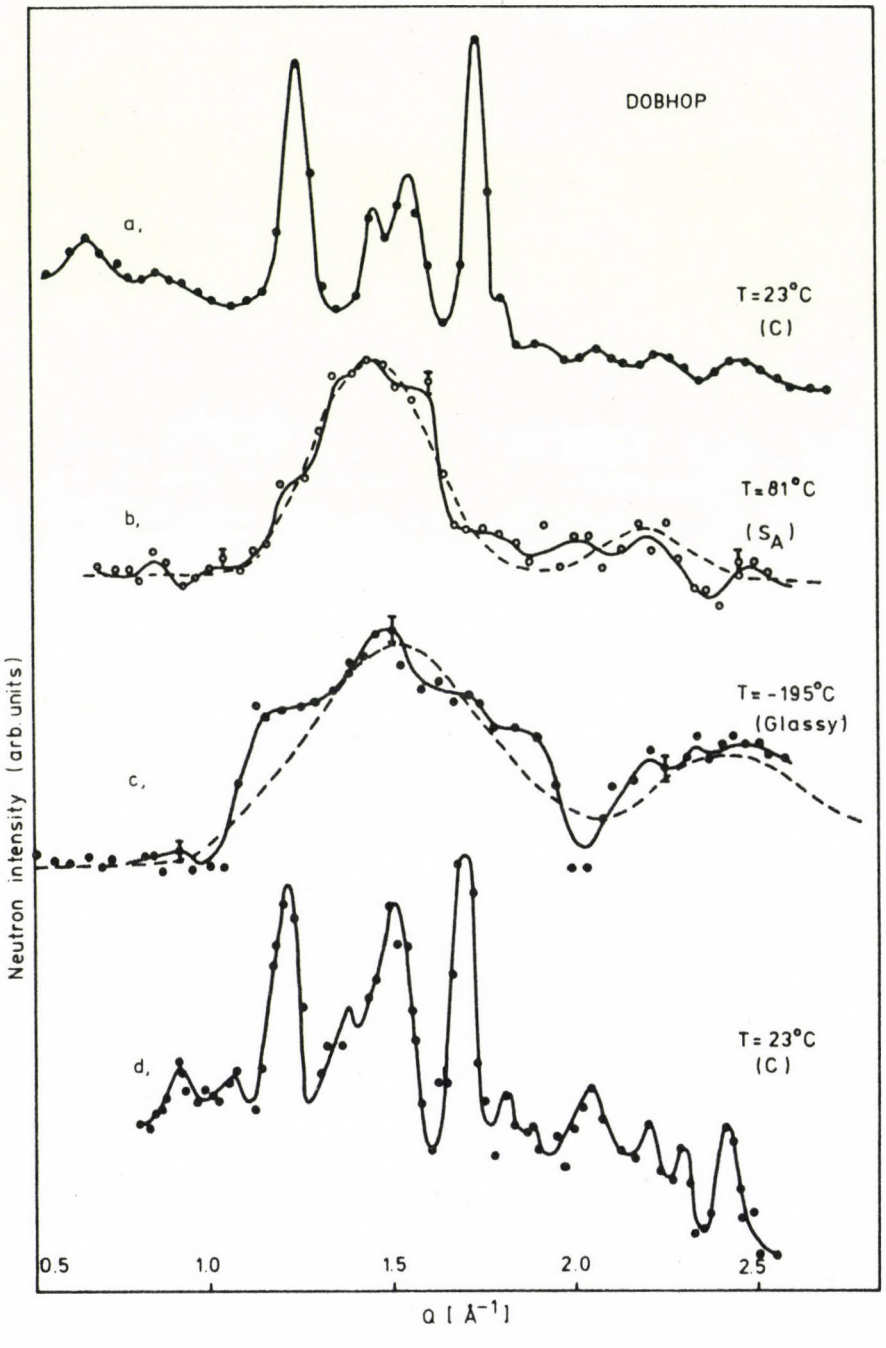


Fig. 7

Neutron diffraction spectra of glassy liquid crystal material (c). Curves (a) and (d) show the structure of the solid; curve (b) shows that of the liquid crystal state

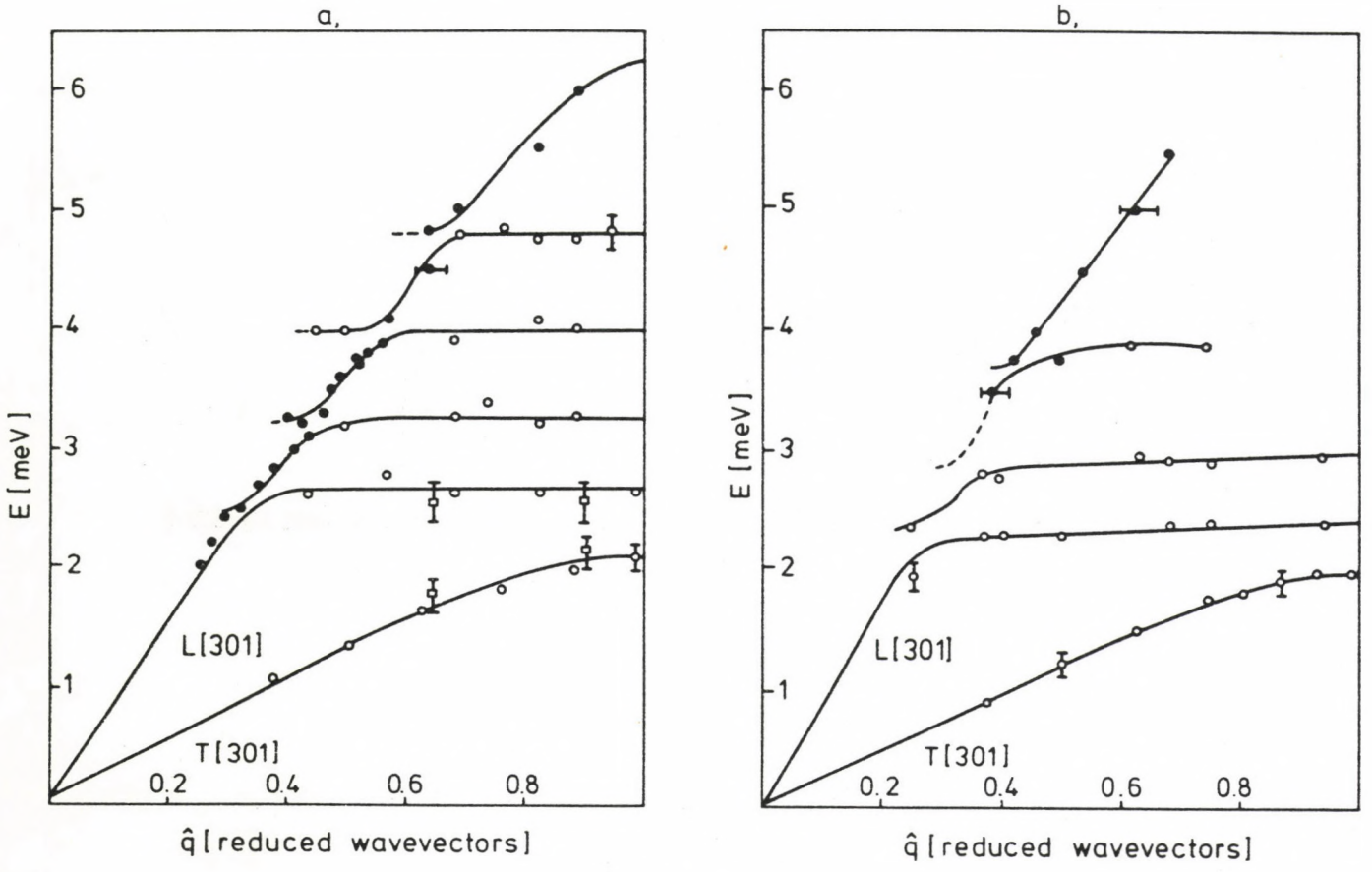


Fig. 8

Phonon dispersion curves of deuterated PAF single crystal in the symmetry direction [301] at two different temperatures: (a) 300 K, (b) 77 K; ● - constant energy scan, o - constant momentum transfer scan, □ - measured in higher Brillouin zone

By the use of the neutron spin echo method neutron scattering studies of elementary excitations were, for the first time, extended to the μeV resolution range. The results complement substantially previous knowledge on the temperature dependence of the energy and lifetime of the roton excitation and the suggested onset of three phonon decay beyond the roton minimum in superfluid ^{4}He. This work was performed in collaboration with Laue-Langevin Institute, Grenoble, France.

PUBLICATIONS: 70, 77, 116, 313, 419, 427, 540, 569, 629

INTERACTION OF HIGH INTENSITY LASER LIGHT AND MATTER

Gy. Farkas, Z.Gy. Horváth, Zs. Szentirmay

The research work done by the team during 1978-80 was concentrated on three topics.

We investigated the spectral distribution of the light originating during the course of the multiphoton processes induced by picosecond Nd:glass laser pulses. The experimentally obtained spectrum *(Fig. 9)* is substantionally in agreement with the theoretical predictions of coworkers of the Lebedev Physical Institute, Moscow, around the wavelength corresponding to the second harmonic of the laser.

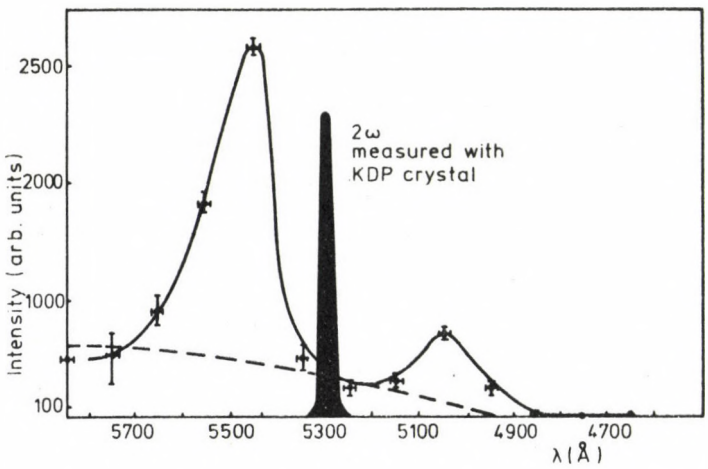


Fig. 9

Spectral distribution of the light originating during multiphoton photoeffect induced by picosecond laser pulses. (The dark area represents the second harmonic of the exciting laser light.)

Several different configurations of the two-dimensional "Halo" laser were realized in cooperation with researchers of József Attila University, Szeged, and of the Lebedev Physical Institute, Moscow. In Szeged we built lasers working at different wavelengths with 25 Hz repetition rate and verified the existence of the laser process. In Moscow, in the course of excitation of the Halo laser by a picosecond laser pulse train, we detected plane laser pulses *(Fig. 10)* whose time distributions are drastically different from those of one dimensional lasers *(Fig. 11)*.

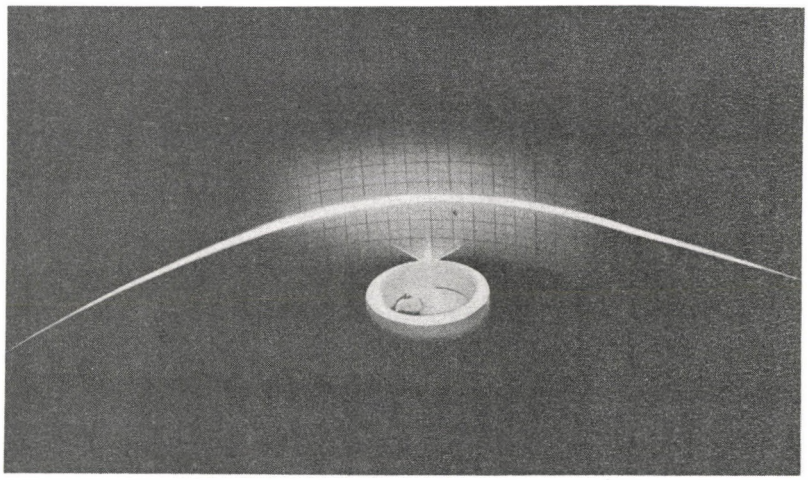


Fig. 10

Rhodamin 6G "Halo" laser emitting planar (div: 3 mrad) radiation. (Repetition rate: 25 Hz; 5 ns pulses)

Figure 11 shows the "halo" light for intensities of the exciting light increasing gradually from a to f. The detected light which is still only a fluorescence in *Fig. 11/a* shows a nearly continuous transition to a real "halo" laser train depicted in *Fig. 11/f*.

Figure 11/f reveals two surprising properties of the "halo" laser excited by the mode-locking train. First, the halfwidth of the "halo" pulses exceeds more than 1 nsec, that is, by two orders of magnitude, longer than the exciting pulse. Second, the "halo" pulse lengths increased within a train from pulse to pulse, e.g. from 1.5 nsec in the first to 2.7 nsec in the last pulse.

These results can be explained by the following: The modes remaining in the cuvette because of the total inner reflexion, represent in the laser material an energy storage or a secondary excitation independent from the primary excitation time. The lifetime of the emerging light is

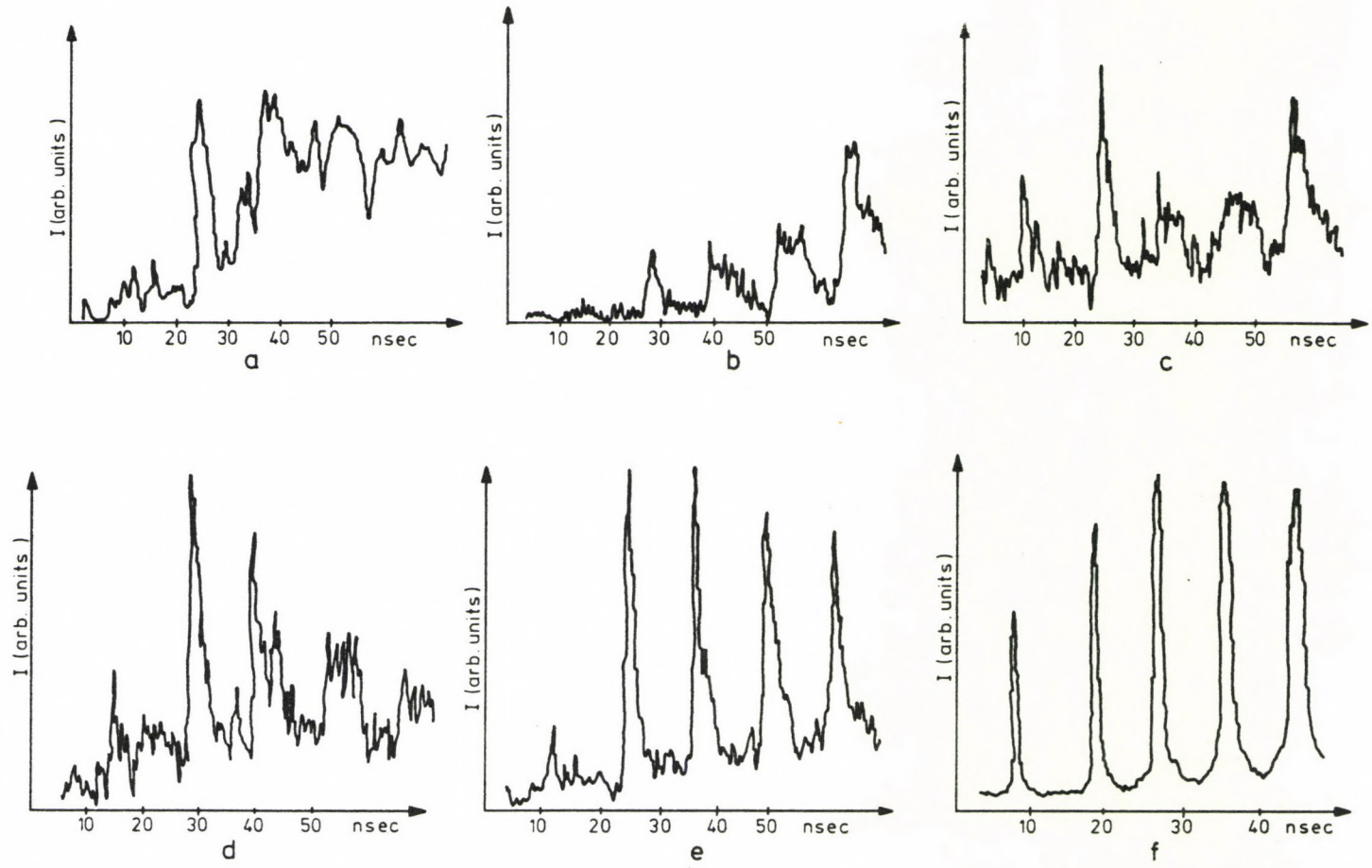


Fig. 11

"Halo" light intensity excited by train of picosecond pulses at increasing pumping from a to f. "a" corresponds to the fluorescence and "f" to the laser emission

determined by the time needed for the energy to be pumped from the imprisoned modes into those capable of emerging.

Investigations on the light emission from aluminium- Al_2O_3- silver tunnel diodes were carried out as a function of the DC bias and temperature. In the case of similar diodes evaporated on holographic grating substrates, the dispersion relation of the emitted light was determined from its spectral and spatial distributions. It was concluded that in contradiction to existing theoretical models, light originates from the decay of surface plasma oscillations on the outer surface of silver. Similar results were also obtained by determining the attenuation length of hot electrons in silver layers.

PUBLICATIONS: 143, 159, 289, 416, 446, 487, 488, 565

INSTITUTE FOR
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RESEARCH

ZR-6M CRITICAL ASSEMBLY

L. Gácsi, A. Gizella, Z. Szabó

Experimental work at the ZR-6 critical assembly was suspended in 1977 and the facility was reconstructed. As a result of this, experimental work could be resumed in 1979 at the modified assembly (ZR-6M, see *Figs. 1, 2*).

The core of the facility is inside a cylindrical tank (core tank, ZT) with a diameter of 1200 mm, height 800-2000 mm. The fuel elements are supported by a solid plate, 250 mm above the bottom of ZT, thus the thickness of the lower reflector can be considered infinite. The height of ZT is variable by stacking annuli of different heights when critical water levels are between 500 and 1000 mm.

ZT is inside a pressure vessel (reactor vessel, RT), 1 m above its bottom. Thus, the space under ZT holds about twice as much water as is necessary to fill ZT entirely.

Electrical heaters and cooling pipe coils are to be found in the lower part of RT. Pressure in RT can be adjusted with the help of nitrogen-gas cylinders or compressed air.

When starting the reactor, water is pumped from RT into ZT. The water level is measured by two float-type level gauges (coarse measurement) and a contact-type fine level gauge.

The reactor is controlled by adjusting the water level or by a manual rod which can be mounted in the centre of the core.

Nuclear safety is assured by safety rods of asteroid section made from borated stainless steel and fast drain valves which dump the water from ZT into RT.

Technical characteristics:

thermal power	100 W
flux of thermal neutrons	2.10^8 n/cm^{2}s
moderator temperature	20-130 ^{o}C
absolute pressure in RT	4.5 bar
concentration of boric acid	0-7 g/l

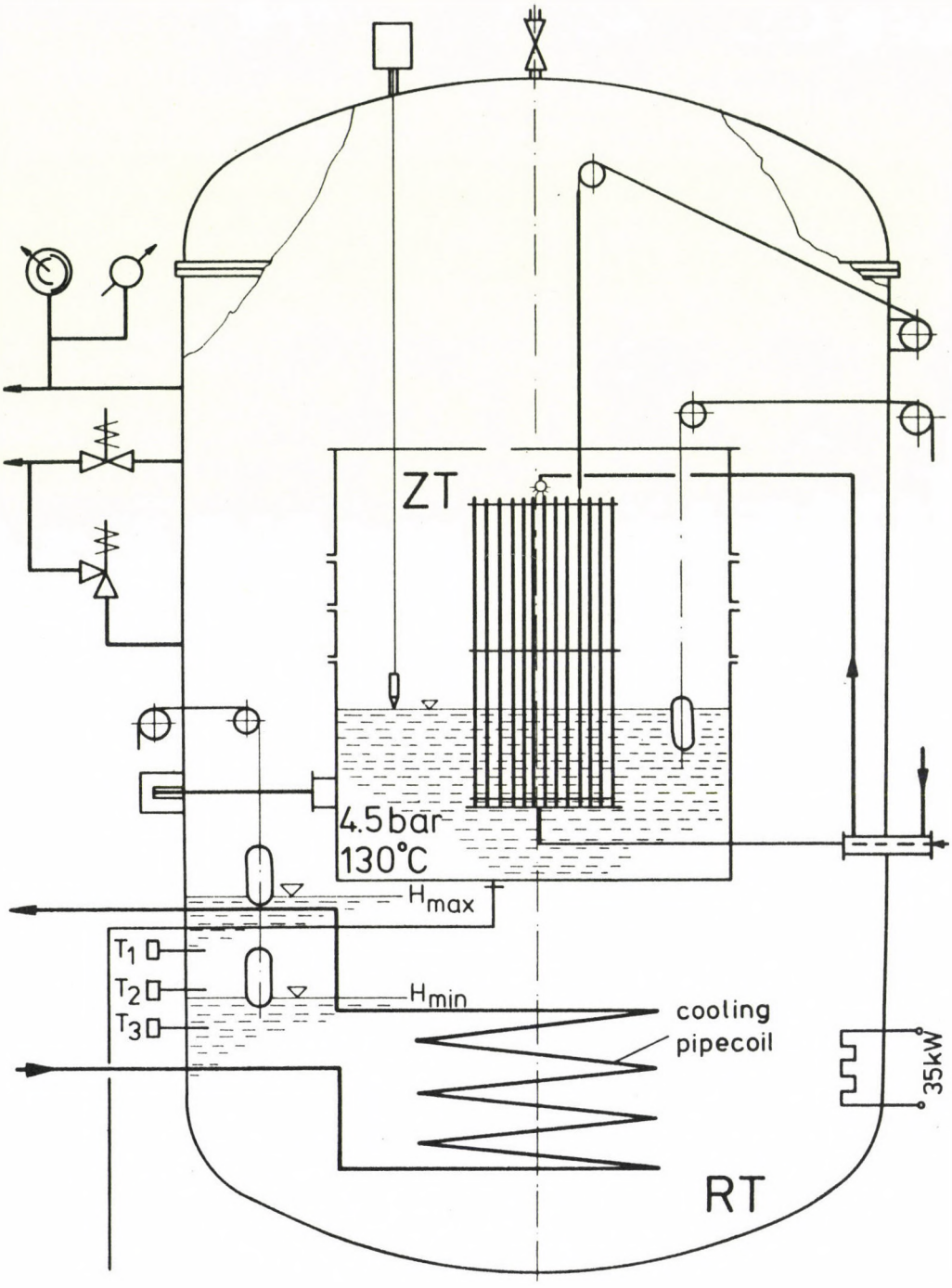


Fig. 1

Section of ZR-6M Reactor Vessel (ZT: Core tank, RT: reactor vessel)

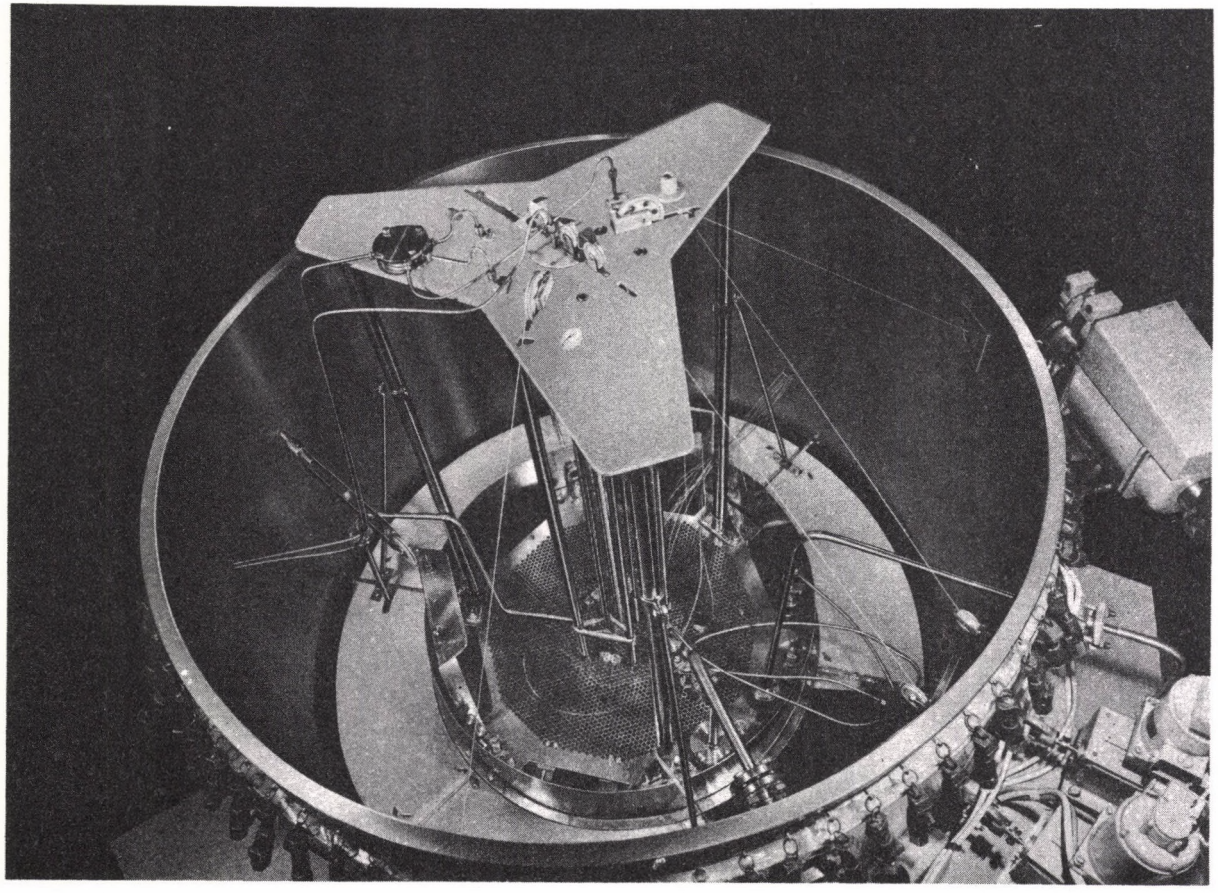


Fig. 2
Core of ZR-6M

REACTOR PHYSICS

F. Adorján, Éva Balog-Izsák, L. Bod, T. Czibók, A. Dévényi, J. Gadó, G. Hegyi, A. Keresztúri, A. Kondor, K. Kriniss, I. Lux, M. Makai, L. Meskó, I. Pázsit, G. Pór, Z. Szatmáry, Margit Telbisz-Pósch, J. Valkó, J. Végh, P. Vértes, I. Vidovszky, M. Zágoni

Before a new series of experiments with the pressurized ZR-6M system could be started, it was necessary to carry out safety investigations concerning the effect of a sudden accidental depressurization of the reactor. In these experiments pipe rupture was simulated by the release of a magnetic valve. The cross sectional area of the valve was in excess of the cross section of the largest pipe in the system. Due to the sudden depressurization the moderator in the reactor begins to boil which in turn results in an increase of moderator level and a decrease of moderator density. The calculations indicated a decrease of reactivity as the net effect of these two effects. The experiments confirmed the calculational results.

The time dependence of the system's pressure and of the reactivity are shown in *Fig. 3*.

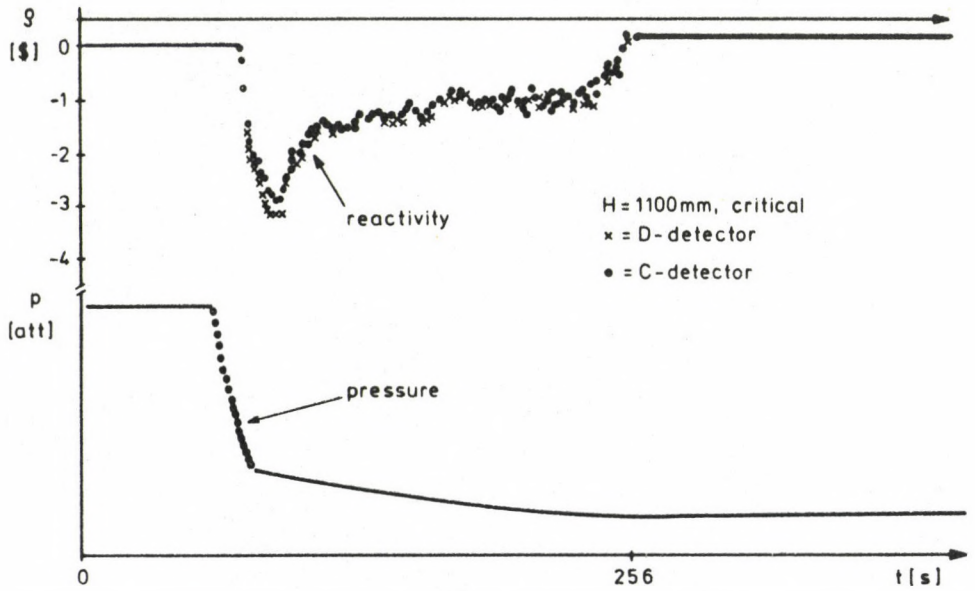


Fig. 3

Time-dependence of the system's pressure and of the reactivity in ZR-6M depressurization experiments

Reactor physics experiments were started at the modified critical facility ZR-6M at the end of 1979. Static parameters which had been measured during the previous five year period were measured at different

elevated temperatures, and the temperature dependence of reactivity was studied. This period of experiments was completed by the summer of 1980. It was concluded that most experimental techniques and methods which had been developed needed only minor modifications for application at higher temperatures. The high temperature operation with its inherent complications, on the other hand, slowed down the rate of measurements. The complete set of experiments was carried out only on two configurations, on the "basic" lattice and on one perturbed one. All experiments are now performed by means of on-line computer-based measuring equipment. The static parameters are measured with a PDP 11/10 system and the reactivity and time dependent measurements use a TPA/i-CAMAC system.

In the experimental period beginning with autumn 1980, measurements are done with a moderator containing boron. This fact necessitated the experimental verification of the negative reactivity effect of depressurization also in the case of a borated moderator.

The program system developed for core-calculations has been applied to various types of reactors. Calculations were performed for the initial load of the first block of the Paks WWER-440 nuclear power station. Other calculations were done in connection with the propagation of primary coolant activity and with design problems of a spent fuel storage facility. For the modernization of the WWR-SM research reactor detailed core calculations and shielding calculations have begun. The comparison of calculation results with ZR-6 reactor experiments has been continued.

The present stage of development in the field of core calculations as well as the requirements for further development have brought about the need to redesign the basic organization of these programs. For this reason, the development of a modular program system was initiated and its essential frame (the unified structure of data files, the main control program and the specification of the individual modules) was completed.

In the course of data-library developments a new library, based on KEDAK-3 files, was constructed and preparations are under way for using ENDF/b-IV. Testing of the basic algorithms such as the treatment of resonance absorption is in progress.

It has been verified that the algorithms and program correctly described the essential neutronic processes of the WWER-440 type nuclear reactor.

The aim of radiation damage studies is the determination of the spatial distribution of microscopic defects (such as vacancies and interstitial atoms) in structural materials caused by radiation. The general, spatial-, angular- and energy-dependent solution of the transport equation that describes the problem is not yet known, therefore research

proceeds by smaller, approximative steps. Two different approaches proved to be successful. First, in the case of identical projectile and target materials the space-energy dependent transport equation was solved in a half-space for the realistic case of cross-sections being proportional to powers of the energy. Second, for constant cross sections the collision density and leakage or sputtering spectrum was determined, also in a half-space, in the case of material mixtures of any number of components. Throughout these derivations the so-called synthetic scattering function was used in which angular and energy dependence are decoupled and which later will have to be replaced by a more realistic function.

Theoretical activity in the field of reactor noise is concentrated on the study of neutron flux fluctuations as they reflect operational or abnormal conditions in the reactor. In connection with the problem of propagating bubbles and density fluctuations in the moderator, the determination of the local diffusion and the measurement of the flow velocity using only one detector was theoretically elaborated taking into account the final length of the neutron detector. By formulating the two-dimensional form of the transfer function a method is suggested for the determination of the trajectory of a vibrating fuel pin or absorber using 2 or 3 neutron detectors and thereby for the localization of a fault which results in this excessive vibration.

Experimental reactor noise investigation began in 1980 in an international cooperation at the nuclear power station Rheinsberg, GDR, where a specially instrumented fuel assembly with provision to reduce the coolant flow to a fraction of its nominal value, was inserted into the core. For this cooperation the pressure and flow measuring equipment was developed and manufactured by our Institute and Hungarian scientists took part in the hydraulic tests and in the actual experiments at the reactor. During the experiments a selection of nuclear and nonnuclear signals was recorded on multichannel magnetic tape under various operational conditions including the case when the coolant in the assembly begins to boil. Evaluation of the recorded information took place in the Institute by a Fast Fourier Transform based signal analysis program system that was developed recently for reactor noise studies. The interpretation of the evaluated noise patterns is currently in progress.

PUBLICATIONS: 35, 36, 79, 204, 226, 227, 228, 271, 334, 348, 359, 558, 559, 560, 562, 568, 598, 599, 600, 690

THERMOHYDRAULICS

T. Beszeda, Magdolna Dus, Gy. Egeli, Gy. Ézsöl, Gy. Gyenes, T. Katona, E. Maetz, L. Maróti, L. Perneczky, L. Szabados, I. Tóth, I. Trosztel, J. Vigassy, P. Windberg

The major part of the experimental work on the NVH high-pressure test loop was carried out under the contract between our Institute, the Kurchatov Institute of Atomic Energy and the Gidropress Organization, Moscow, USSR. The aim of these tests was to investigate the effect of shroud perforation on critical heat flux. The experiments were performed on test sections consisting of two 5-rod bundles with a shroud of 3 per cent perforation in between *(Fig. 4)*. Three cases were examined:

a) The two bundles are divided by a water gap of 3 mm;

b) The bundles are divided by a water gap of 6 mm;

c) There is no water gap between the bundles.

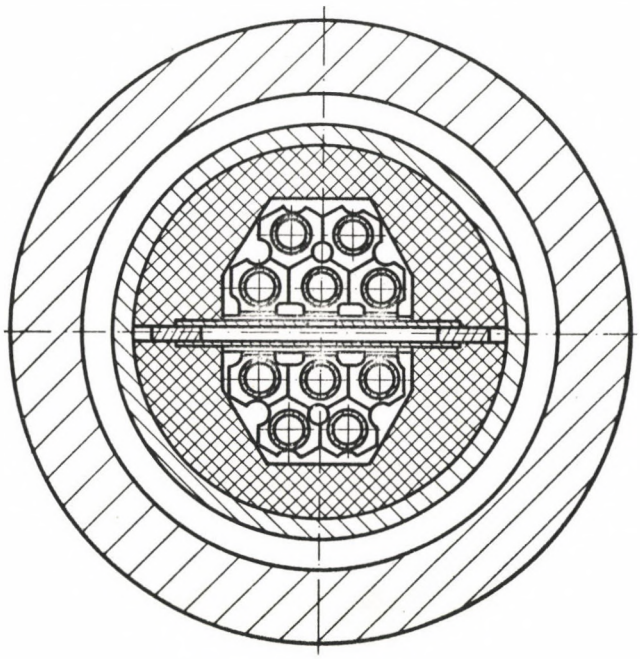


Fig. 4
Cross sectional view of ten-rod bundle

Moreover, the distance between fuel elements and the shroud was varied.

The computer code PUCHOK-3C - a new version of COBRA-3C developed at our Institute - was used in the interpretation of the above tests. Calculations compared well with the experiments.

Based on the experiments, calculations were also carried out for real fuel-assemblies. These showed that the perforation had a local effect on critical heat flux and, depending on bundle design, could either increase or decrease its value by a small amount.

It is envisaged that next year ECC experiments will start under the same contract. Draft and design of a single-rod test-section for reflood experiments has been completed.

In addition to our earlier single-rod tests with power transients, loss-of-flow type experiments were run to investigate their effect on critical heat flux. It was found that with decay speeds ranging between 30 and 90 per cent/s the quasistatic approach is valid.

Analyses were performed to investigate the LOCA behaviour of the WWER-440 type reactor. Calculation of a cold-leg-break case was carried out with RELAP/mod3. Under the contract between KKAB, Berlin, GDR, ERŐTERV, Budapest, and our Institute the BRUCH-D-04 and BRUCH-D-06 codes were run to analyse LOCA with and without the passive ECCS.

Important results have been obtained in a better understanding of blowdown heat transfer. One of our research engineers participated, at the Centre d'Études Nucléaires de Grenoble, in the interpretation of blowdown experiments: the results will permit the updating of heat transfer models of blowdown codes.

Thermal non-equilibrium phenomena play an important role in safety analysis, e.g. in the calculation of critical flow. With the aim of modelling the latter process the code describing bubble growth has been modified to incorporate arbitrary variation of system pressure with reduced computer time.

The stochastic character of boiling and two-phase flow has been investigated theoretically and experimentally. The acoustic noise of subcooled boiling and the criteria of acoustic detection of boiling were studied.

Experiments were performed to analyse temperature and pressure fluctuations as well as the dependence of physical relations between these signals on different flow regimes. It was found that the integral coherence of the two signals strongly depends on the flow pattern and it can be used for its identification *(Fig. 5)*.

Engineers of the department participated in pre-test and "in situ" calibration, as well as in the first experiments on the diagnostic fuel assembly loaded in the Rheinsberg Power Station, GDR.

An important role was played by the department in the preparations for the reconstruction of the WWR-SM research reactor, e.g. in the analysis of decay heat production and in defining the basic principles and design of the ECCS.

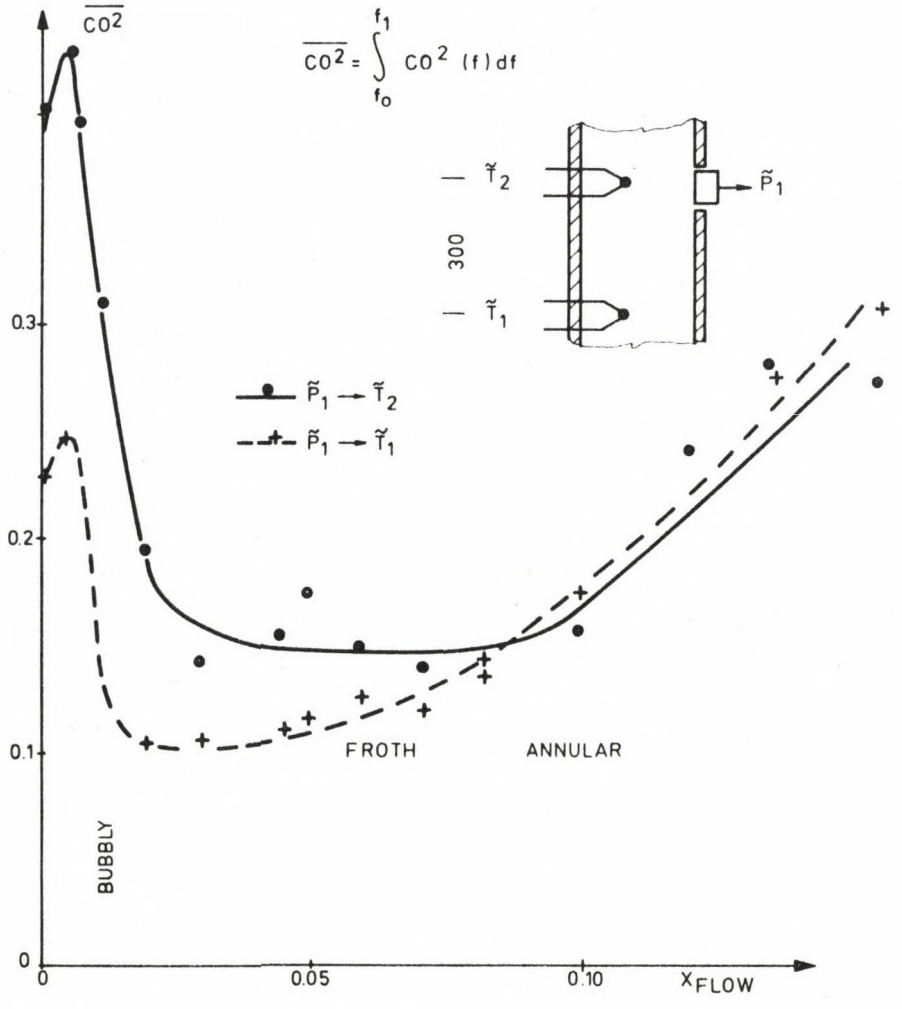


Fig. 5

Integral coherence of pressure and temperature fluctuations versus steam quality

PUBLICATIONS: 97, 278, 327, 349

COMPUTERIZED REACTOR CONTROL

Laura Bürger-Pátkai, A. Gossányi, J.S. Jánosy, K. Nyéky, Gy. Sándor, G. Szabó, Zsuzsa Szegi, E. Végh, E. Zobor

On the basis of our earlier experiences in the field of computerized reactor control, in 1979-80 the main activity of the department was concentrated on the development of a reactor monitoring computer system for a 10 MW research reactor. We exported this system, as subcontractor of the Soviet Organization ATOMENERGOEXPORT, to Libya. The main tasks of the delivered reactor monitoring system are the following:

- calculation of the surface boiling factor of the reactor every 15 seconds,
- monitoring the burn-up of the fuel elements,
- fuel administration,
- correction of the sensitivity of the in-core detectors against their burn-up,
- rod calibration.

The problem was solved, as in our earlier works, by an ES 1010 process computer configuration using the PROCESS-24K operating system.

We increased the availability of our own computer control system of the 5 MW WWR-SM research reactor by developing a dual-processor system. The installation of the second computer was successfully terminated and we finished the connection of the peripheral bus of the two processors. The development of the coordinator unit of the dual system has now ended and at present we are working on the operating system of the dual-processor configuration.

The work in the field of computerized alarm and disturbance analysis has been continued. We have developed the first version of an alarm analysis program and we use it in a PDP-11 computer configuration. The off-line failure analysis of the main circulating pump, the pressurizer, the turbine, the droplet separator and the condenser of the Paks Nuclear Power Plant are finished. A simplified complete dynamic model of the primary circuit of the WWER-440 power plant was developed in close cooperation with the Bulgarian Institute for Nuclear Energy and Research, Sofia, by which we can study the controllers and the malfunction of the main units of the primary cooling loop.

A 200-channel data collecting computer system is under development in our department for the Paks Nuclear Power Plant. This is a mobile TPA/i computer configuration with industrial CAMAC peripheral system. The data are recorded on floppy disc for later analysis. The system will be used during the commissioning period of the Power Plant.

PUBLICATIONS: 65, 165, 314, 342, 688, 689

INSTRUMENTATION FOR REACTOR PHYSICS AND TECHNIQUES

A. Baranyai, P. Pellionisz, L. Várhalmi, J. Zsidó

In 1979-80 the development and application work was continued in the field of reactor instrumentation. The Instrument System for Nuclear Industry that we developed earlier has been extended by new system units such as test generators, converters, scalers, etc. The documentation of a large collection of system units has been prepared for industrial manufacture since the production licence of the instrument family has been bought by the GAMMA Works, Budapest *(Figs. 6 and 7)*.

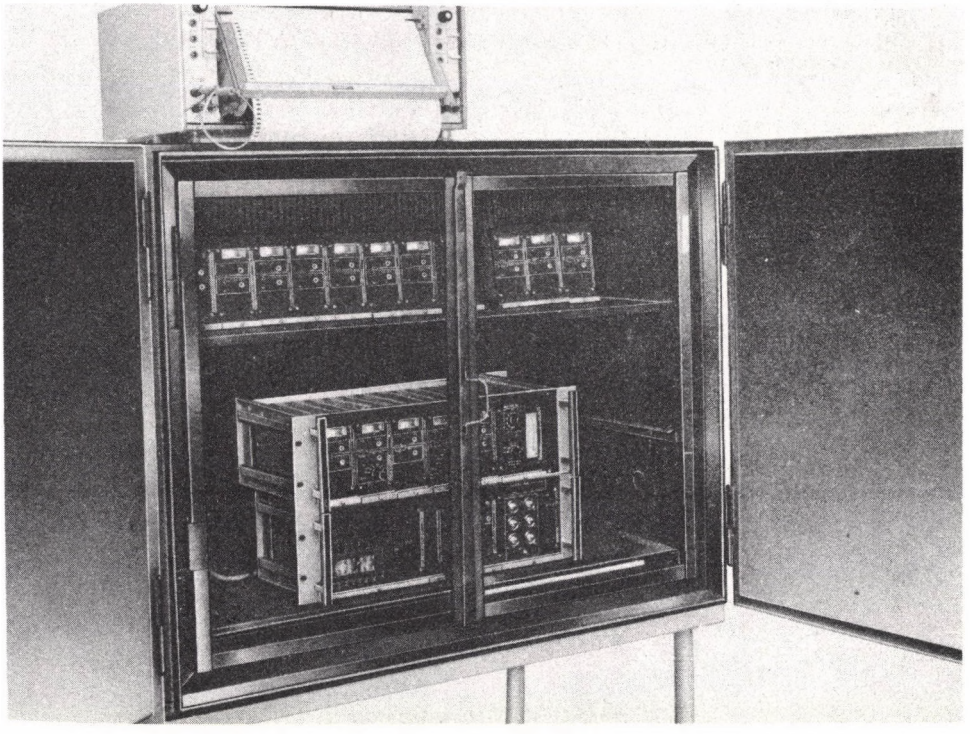


Fig. 6

Ageing process of modules and channels

We continued the application of the instrument family at several research facilities such as the ZR-6 critical system or the training reactor of the Technical University of Budapest.

The reactor-physical parameter monitoring system designed for start-up measurements at nuclear power reactors was completed during 1979-80. Besides the completion of the data collection hardware, intensive soft-

ware development was carried on. A data collection software package named COMMAND has been elaborated and program modules have been written for reactivity coefficient calculations. Hardware and software were tested at the ZR-6M critical facility and in start-up measurements at nuclear power reactors in Czechoslovakia and in Bulgaria.

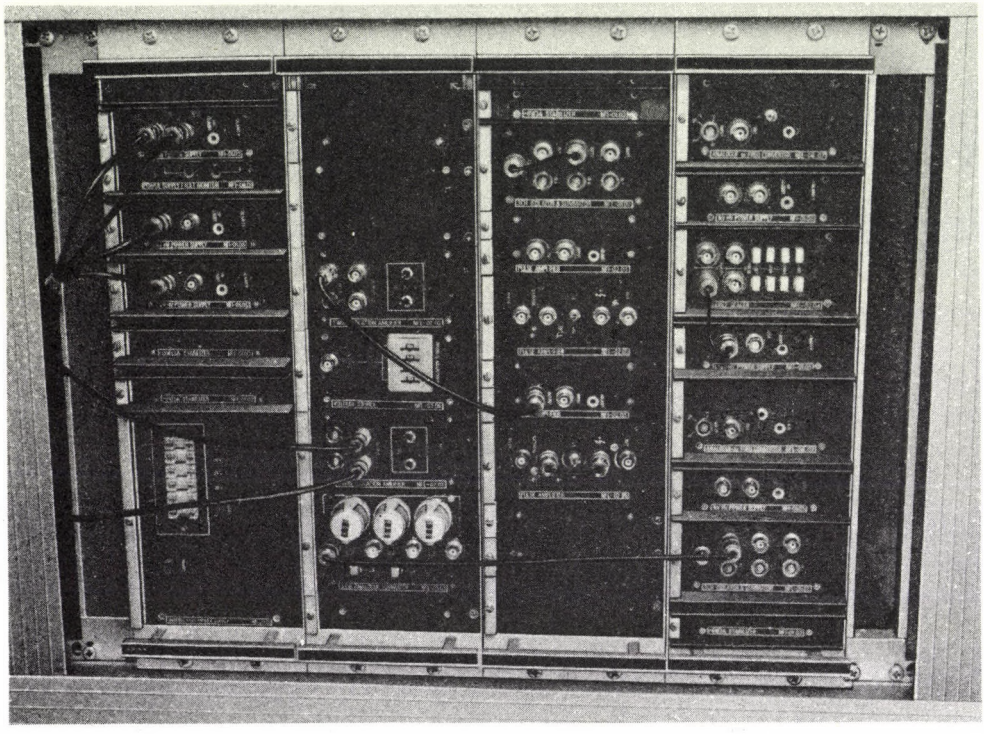


Fig. 7

Experimental setup from the modules of the Instrument System for Nuclear Industry

In addition to these large research and development programs a number of instruments were built for supporting reactor physics research (preamplifiers, sample changer automation units, etc.).

PUBLICATIONS: 30, 79, 359

ACOUSTIC EMISSION RESEARCH AND DEVELOPMENT

P. Pellionisz, A. Péter, L. Zeke

Acoustic emission technique is a modern nondestructive material testing method. The main goal of the research and development work in this field is to establish the methodological and instrumentational basis of this technique in Hungary.

The development of a 32-channel computerized acoustic emission fault localizing and analysing system reached an advanced stage: the system of the modular intelligent data acquisition part was worked out, and eight different types of modules have been developed.

Preparations were made to test certain parts of large size pressure vessels by a four-channel acoustic emission measuring and fault localizing system developed specially for such purposes.

The testing of various steel materials has been continued; basically two sorts of measurements were performed: fracture mechanical tests of several types of welding materials on small scale three point bending specimens and stress corrosion cracking processes *(Fig. 8)*.

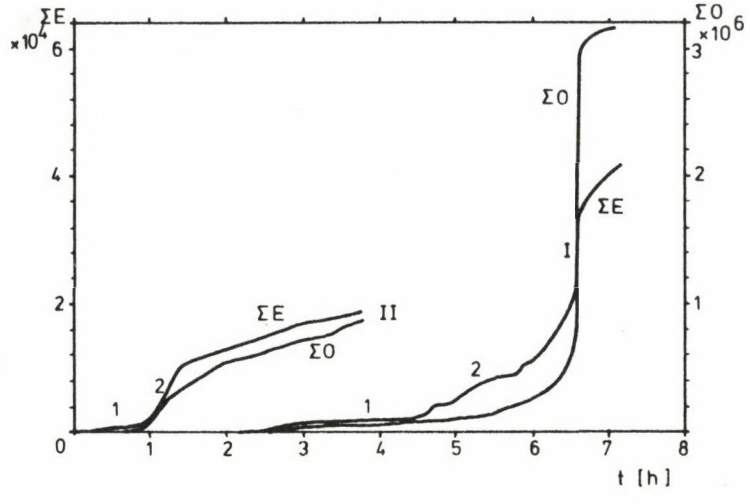


Fig. 8

Accumulated number of acoustical events (E) and oscillations (O) for two test specimens (I and II) as a function of time during a stress corrosion measurement

PUBLICATION: 604

SPACE ELECTRONICS

I. Apáthy, I. Szemerey, S. Szendrő

Following our previous work we have finished the development and manufacture of three apparatuses measuring the characteristics of the ionosphere. They will be launched on board a satellite and geophysical rocket in 1981. The interpretation of ionosphere data obtained by the geophysical rocket "Vertical-6" has been continued *(Fig. 9)*.

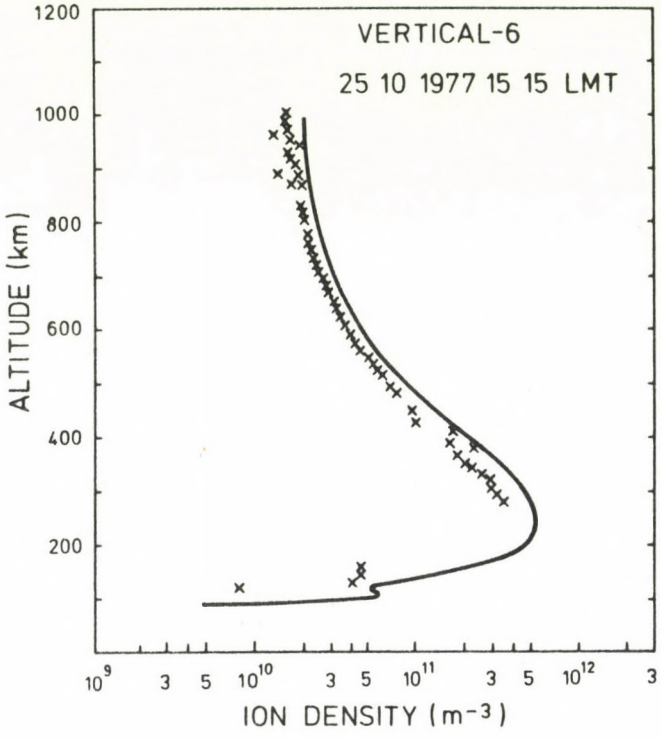


Fig. 9

Electron density profile computed on the basis of the International Reference Ionosphere 1978 for the time of apogee of the geophysical rocket "Vertical-6". Measured total ion densities are denoted by crosses

The development and construction of a microprocessor-controlled unit surveying some special features of the solar wind, ionized comet regions and the ionosphere of other planets has been started.

PUBLICATIONS: 20, 317, 372, 405

WHOLE-BODY COUNTING AND GAMMA SPECTROMETRY

A. Andrási, Éva Beleznay, I. Németh, P. Zombori

A recommendation for the monitoring system of radiation doses from internal contamination due to occupational exposure of workers in the Paks Nuclear Power Plant was completed.

The development of the whole body counter with two-detector scanning geometry was set up (mechanical movement of bed and detectors) and the two NaI(Tl) detectors were equipped with focusing collimators for profile scanning measurements.

A set of codes for data processing and evaluation was written for a PDP 11/34 computer.

A program system (MEASSYS) was developed for controlling the measurement and evaluating the spectra of the semiconductor spectrometer consisting of a Czechoslovak-made Ge(Li) detector and electronics produced by the Works for Electronic Measuring Gear, Hungary.

PUBLICATIONS: 1, 14, 15

DOSIMETRY STUDIES

L. Koblinger, J. Pálfalvi, B. Szabó, P.P. Szabó

A dosimeter evaluation system to be used at the Paks Nuclear Power Plant was developed for both gamma and neutron radiations. In the framework of this, the adjoint Monte Carlo code REBEL-2, written originally for calculating the exposure rates in dwelling rooms, has been extended to the calculation of doses absorbed in several critical organs of an anthropomorphic phantom.

To obtain the maximum absorbed neutron dose in the body, detector signal to dose conversion factors were calculated and measured at the

Training Reactor of the Technical University of Budapest and at a zero power reactor. For the measurements several types of tissue-equivalent plastic track detectors were developed and their properties were investigated. To measure automatically the track densities a VIDIMET 2 type image analyser was constructed and installed. To have more reliable gamma dose values in mixed neutron and gamma radiation fields, the neutron and photon energy sensitivities of TL detectors of various types were studied using a thermoelectrically cooled laboratory TLD reader TLD-04B-TC linked with a teletype to facilitate the evaluation by a PDP 11/34 computer.

PUBLICATIONS: 110, 197, 232, 430, 495, 526, 527, 594, 595, 631

SPACE DOSIMETRY

S. Deme, I. Fehér, B. Szabó, P.P. Szabó

A small, portable, vibration and shock resistant thermoluminescent dosimeter (TLD) system (PILLE) *(Fig. 1)* was developed to measure the cosmic radiation dose on board a spacecraft. The TLD system consists of a special bulb dosimeter and a TLD reader. The measuring dose range of the TLD system is from 10 μGy up to 100 mGy. The TLD reader can operate on a battery; its electric power consumption is about 5 W, its volume about 1 dm^3 and its mass is about 1 kg.

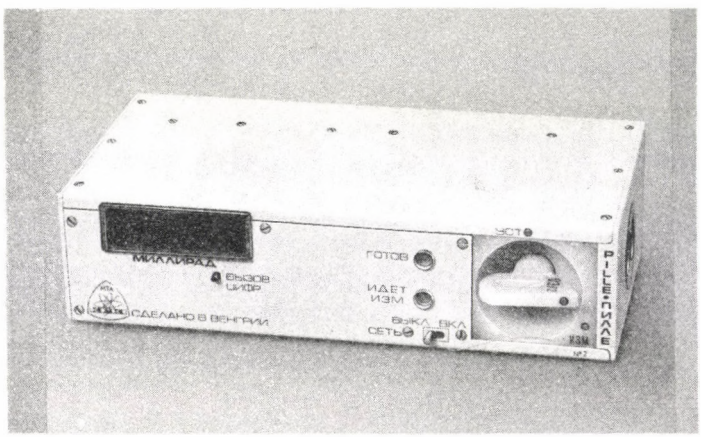


Fig. 1

TL reader instrument "PILLE" used by Bertalan Farkas, Hungarian cosmonaut, on board the "Salyut-6" space station

Measurement of astronauts' dose burden up till now has been possible only after returning to Earth. The TLD reader and the bulbs are able to measure the dose burden during the actual space flight, i.e. immediate and operative dose measurements can be carried out on board a spacecraft. This possibility is especially useful after a space walk or after a sudden solar flare when the dose is expected to be high. Besides the advantages in space application, this TLD system can be used in the environmental monitoring of a nuclear power station as the reader can be operated by a car battery.

During the 3rd main expedition on board the "Salyut-6" orbital station in 1979 the integral characteristics of cosmic radiation were measured in various positions inside the manned modules (experiment "Integral"). Measurements were performed with thermoluminescent dosimeters, photographic films and solid state plastic detectors supplied for the experiment by specialists of the USSR, Bulgaria, GDR, Hungary and Romania.

The difference in the dose observed at various places inside the manned modules of the station amounted to 70% for long periods of time. During the experimental period the dose rate inside the station was 150-300 μGy per day. The mean flux of particles with $Z > 6$ and LET > 200 keV/μm was found to be 0.22 cm^{-2} day^{-1}.

PUBLICATION: 362

ENVIRONMENTAL MONITORING AROUND NUCLEAR POWER PLANTS

A. Andrási, Éva Beleznay, J. Biró, S. Deme, I. Dudás, I. Erdélyvári, I. Fehér, L. Koblinger, Gy. Lancsarics, J. Molnár, Gy. Nagy, I. Németh, P. Ormai, Éva Pados-Farkas, M. Rövid, Gabriella Szabady-Szende, P.P. Szabó, P. Zombori

A number of the measuring and sampling methods which are due to be used in the Paks Nuclear Power Plant were developed. The prototype of the measuring and sampling stations planned to be used in the environment of the nuclear power station was prepared and its testing was finished.

The sampling stations for aerosol, fall out iodine and iodine monitors were fabricated and are being installed on-site. A water sampling system using a 350 cm^3 NaI(Tl) crystal as detector was developed, its efficiency was investigated under a layer of water of 1 m thickness. Electronic devices were produced and set up for measuring the meteorologic parameters needed to calculate the spreading of the radioactive

release. Also a Monte Carlo computer code was developed for computing organ doses and detector responses arising from different gamma sources in the vicinity of a nuclear power station.

A preoperational in situ gamma-spectrometric background measurement program was started with the mobile laboratory in the spring of 1979. Results of measurements at 24 sites in the environment of the power plant performed twice a year will provide sufficient background data for the systematic environmental monitoring to be made in the future.

The measuring program of the environmental sample measuring laboratory, including the system of gamma-spectrometric sample measurements, was completed. The methods and programs for controlling the measurements and evaluating the data were also developed.

Gamma background measurements were commenced; these also use $CaSO_4$:Tm TL detectors which are changed monthly.

PUBLICATIONS: 84, 85, 257, 357

RADIATION PROTECTION SERVICE

A. Andrási, J. Biró, I. Erdélyvári, J. Losonczi, J. Molnár, Éva Pados-Farkas, J. Pálfalvi

The personnel, the working places and the whole area of the Research Centre were routinely controlled; the tasks in connection with isotope handling and with the central records concerning radiation were duly performed by the Radiation Protection Service in order to safeguard the workers from health hazards, and to protect materials and goods from radiocontamination *(Table I)*.

Similarly to earlier years, the dose received by the majority of persons (99%) working in radiation hazardous places did not exceed the maximum permissible dose for a month, i.e. 3.5 mGy.

Table I

METHODS OF PERSONNEL DOSIMETRY

Dosimeters used	Number of workers monitored	Radiation	Time
Kodak RM film	350-400	beta, gamma	monthly
TL	350-400	beta, gamma	1 and 3 months
hand and finger TL	20-25	beta, gamma	when needed
nuclear emulsion	15-20	neutron	when needed
accident	45-50	neutron, gamma	yearly
whole-body counting	55-65	incorporation	once or twice a year
urine investigations	10	^{3}H	monthly
thyroid measurement	10	^{131}I	twice a year

ANALYSIS FOR SOLID STATE RESEARCH

L. Bakos, Mária Csajka, A. Elek, Erzsébet Kelen-Füzessy, F. Molnár, Á.Z. Nagy, Ibolya Sziklai-László, Éva Szirmai-Kulus
Visiting research workers: Mária Lőrincz, H. Rausch, A. Salamon, J.C. Soria, Andrea Varga-Kisbán

Traces and profiles of various elements (sodium, copper, gold, antimony, boron, phosphorus) were determined by neutron activation analysis in silicon, silicon nitride and silica matrices. These investigations were performed in cooperation with Tungsram, Budapest, the Research Institute for Telecommunication, Budapest and the Research Institute for Electronics, Budapest.

Several elements were determined in electronic grade waters for quality control.

In order to establish systematic control of some characteristic parameters for WWR-SM reactor under operational conditions, the activity of water and gas samples taken from the primary circuit was measured regularly for more than two years. No less than 17 fission products and 7 activated tracers in the primary cooling water as well as 6 radioactive components in the gas samples were determined by a non-destructive technique using a Ge(Li) semiconductor γ-spectrometer.

In cooperation with the Research and Planning Institute for the Aluminium Industry, Budapest, work was continued on the determination of the oxygen content in aluminium. New laboratory equipment has been installed for measurements of radioactivity of samples activated by the fast neutrons of a neutron generator, type NG 2.

Determination of the following trace elements was performed in alumina ceramics by means of activation analysis: Ca, Ti, Fe, Ba, Mn, Ga, Zn, Cr, Ce, Ag, Co, U, Th, Hf, La, Sc, Au, Lu, Yb, Eu, Zr, Nd, Ni, Cs, Ta.

PUBLICATIONS: 52, 53, 54, 93, 254, 315, 578, 579

DEVELOPMENT OF ANALYTICAL METHODS

Mária Csajka, Mária Ördögh, G. Pernecki, A. Simonits, E. Szabó

Measurements for the k_o factors were continued and the k_o values of 30 analytically important radioactive isotopes were determined. This work was performed in cooperation with the Institute for Nuclear Sciences, Rijksuniversiteit, Ghent, Belgium.

A new separation method has been introduced for the determination of iodine content in reactor cooling water. The radioactive iodine isotopes are bound on silver iodide precipitate and subsequently measured by a semiconductor detector.

Trace elements were determined by activation analysis in capsicum for the investigation of the metabolism of various elements, especially of iodine. This work was performed in cooperation with the Botanical Institute of the Hungarian Academy of Sciences.

PUBLICATIONS: 82, 83, 126, 127, 218, 247, 248, 623

AGRO- AND BIOANALYSIS

L. András, A. Csőke, A. Fehér, M. Fodor, P. Gróz, L. Hodány, P. Kálmán, Z. Pokó, Szabina Török, Éva Zemplén-Papp

As a result of favourable operational experience with autoPRODET - an automatic laboratory device developed for determining the chlorine and raw protein (nitrogen x k) contents of fodder mixers and fodder bases - the development of new equipment to be integrated into the technological process has been started. The whole measuring cycle (automatic sampling, measurement, sample removal) takes only 600 s, so that the measured analytical data relating to the chemical composition can be used in the process control of a mixing factory or plant.

The second series of measurements on non-destructive nitrogen determination - using the $^{14}N(n,\gamma)^{15}N$ nuclear reaction - in order to select seeds for plant breeding purposes has been continued at the Laue-Langevin Institute, Grenoble, France. The results of the choices made on the basis of our measurements and the yield of the outdoor cultures have confirmed our assumption that non-destructive prompt γ-ray spectroscopy provides new possibilities for selecting seeds for protein content.

A new system of larger capacity for measuring, sample handling and packing has been developed. In the summer of 1980 a third series of measurements began at the Laue-Langevin Institute with the financial support of the IAEA.

PUBLICATIONS: 11, 12, 13, 55, 350, 574

MASS SPECTROMETRY

J. Frecska, L. Matus, I. Nyári, I. Opauszky

The determination of impurities in high quality Al, Cu, Ga and in other substances of different types, serving both research and development, has been continued using the MS 702/R (A.E.I., England) high resolution spark source mass spectrometer.

In agreement with other authors' experiences, better accuracy can be achieved in the spark source mass spectrometric analysis of high purity materials if deeply cooled electrodes are used. In order to obtain quantitative data the relative sensitivity factors (RSF) have to be taken into account. In our earlier experiments we concluded that the logarithmic RSF-values show a linear dependence on the boiling points of the impurities in diluted metals. The concentration of one of the impurities being known (internal standard) those of the others can easily be determined according to the linear log RSF - boiling point dependence.

In cooperation with the Zentralinstitut für Isotopen und Strahlenforschung, Leipzig, GDR, a laser micro analyser (LMA-10, Carl-Zeiss, Jena) is being installed to gain ions from the sample by laser excitation. For this purpose a new ion source chamber has been built. Using laser excitation a detection limit of about 1000 ppm/single shot is expected for a great number of elements with only 1 µg of sample material needed.

A special method has been worked out to determine oxygen in gallium. A high purity gold sample holder was prepared that also served as an external standard for oxygen. The counter electrode was made from the same gold sample. On sparking first gold against gold and then gold against gallium the relative oxygen concentration of the two metals can easily be established knowing the amount of material used up during the analysis. The amount of material used up was determined by weighing. At least 12 hours of preheating the sample and the vacuum system as well as use of a cryopump during the sparking are necessary.

To measure the blackening of spectral lines recorded on photoplates a semi-automatic data acquisition system has been built using a modified photo-densitometer *(Fig. 1)* and appropriate CAMAC units made in the Institute.

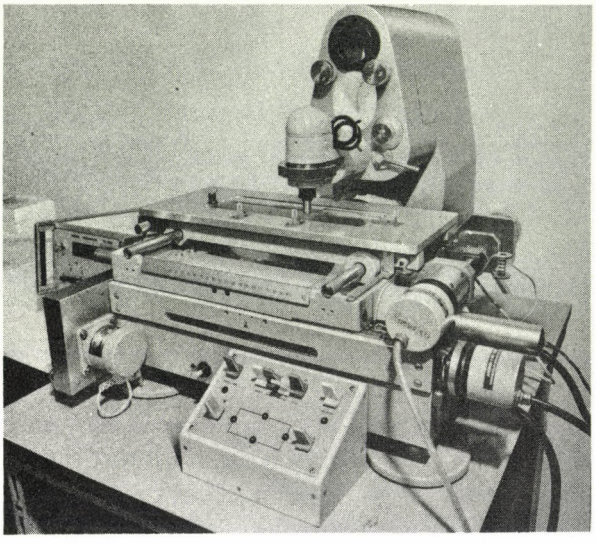


Fig. 1

Computer controlled modified Zeiss G II-type photo-densitometer

PUBLICATIONS: 229, 566

ISOTOPE EFFECTS

Borbála Gellai, Hédy Illy-Vajda, Gy. Jákli, G. Jancsó.

The interpretation of our earlier experimental data on the vapour pressure of the equimolar C_6H_6-C_6D_6 system showed that the molar volume isotope effect plays an important role in the deviation of this system from the ideal behaviour. Since the few data on the molar volume isotope effects of benzenes and cyclohexanes available in the literature show a large scatter both in their magnitudes and temperature dependences, we carried out new measurements in the temperature range of 15 to 70 ^{o}C.

As a continuation of our earlier investigation on the behaviour of isotopic mixtures, the vapour pressure differences between H_2O and the equimolar H_2O-D_2O mixture were measured between 5 and 90 ^{o}C. For com-

parison the vapour pressure differences between pure H_2O and D_2O were also determined. The results show that the H_2O-HDO-D_2O liquid misture does not deviate from the ideal behaviour within the limits of experimental error and they support the earlier conclusion that the law of the geometric mean for the vapour pressure isotope effect in the series H_2O, HDO and D_2O is not obeyed.

Our experimental data on the vapour pressure difference between CH_3CN and CD_3CN which were obtained by differential capacitance manometry between -40 and +80 ^oC were interpreted within the framework of the statistical theory of isotope effects in condensed systems. Detailed analysis showed that the largest contribution to the vapour pressure isotope effect arises from the shifts in the CH stretching vibrations on condensation which were found to be temperature (density) dependent in accordance with the available spectroscopic information. The results also indicated that the rotation of the molecules about the 3-fold symmetry axis in the liquid phase can be considered quasi-free whereas the rotations about the axes perpendicular to the top axis are restricted.

According to recent investigations on the isotope effects on Mössbauer spectra parameters of $FeSO_4 \cdot 7H_2O$, $FeSO_4 \cdot 7D_2O$ crystals as well as solutions of $FeSO_4 \cdot 7H_2O$ and $FeCl_2 \cdot 4H_2O$ in $H_2{}^{16}O$, $D_2{}^{16}O$ and $H_2{}^{18}O$ there is a significant difference (0.04 mms^{-1}) in the quadrupole splitting in the frozen solutions of $FeSO_4 \cdot 7H_2O$ in $H_2{}^{16}O$ and $D_2{}^{16}O$; this difference further increased in 70 mol% $H_2{}^{18}O$ solution for which a value of 0.06 mms^{-1} was observed. However, no isotope effect was found for the quadrupole splittings in the frozen H_2O and D_2O solutions of $FeCl_2 \cdot 4H_2O$ and for the crystalline $FeSO_4 \cdot 7H_2O$ and $FeSO_4 \cdot 7D_2O$ at room temperature. The experimental findings could be qualitatively accounted for by taking into consideration the differences in the distances of the closest approach of the water oxygen atoms to the iron brought about by the isotope substitution as well as by other parameters such as hydrate structure and temperature.

The investigation of the relationship between the vapour pressure isotope effect and the change in anharmonic constants on condensation from vapour to liquid has been continued by comparing the vapour pressure of $CHCl_3$ with that of $CDCl_3$. The measurements covered the temperature range of -60 to +60 ^oC and the interpretation of the experimental data is in progress.

PUBLICATIONS: 162, 163, 194, 492, 493, 494, 497, 498, 499, 500, 501, 502, 503

HOT ATOM CHEMISTRY

Klára Berei, Ágnes G. Csató-Nagy, L. Matus, L. Vasáros

The influence of chemical and physical properties of the media on stabilization processes of (n,γ) produced ^{38}Cl atoms in dichlorobenzenes (DCB) was investigated in cooperation with the Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.

To get more information on the role of thermal processes in the liquid cage competing with the hot ^{38}Cl-for-Cl replacement, the effect of elementary iodine scavenger, present in a small amount, was compared with the effect of solvents - present in high concentration - possessing different reactivities towards thermal chlorine atoms. In the latter case the reactivity of the cage wall itself was altered. From the results the conclusion could be drawn that in media showing any affinity towards thermalized recoil atoms the usual scavenger amounts are sufficient to compete with thermal recombinations also in the liquid cage. However, if the parent molecule is surrounded by a cage wall inert or repulsive towards recoil atoms, as in the case of systems highly diluted with perfluorinated hydrocarbons, it seems to increase the probability of thermal processes which cannot be suppressed completely by small amounts of scavenger. *Figure 2* shows the influence of C_6F_6 concentration in its mixtures with DCB on the ^{38}Cl-for-Cl and ^{38}Cl-for-F replacement yields and their ratio.

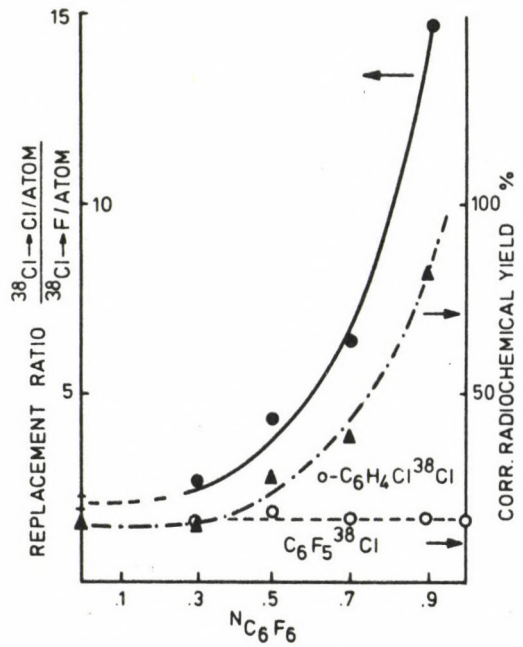


Fig. 2
Ratio $\frac{^{38}Cl \longrightarrow Cl}{^{38}Cl \longrightarrow F}$ *and radiochemical yields (corrected for dilution) vs mole fraction of* C_6F_6 ($N_{C_6F_6}$) *in liquid systems* $o\text{-}C_6H_4Cl_2\text{-}C_6F_6$ + 0.5 mole% I_2

Experiments carried out with the α, β and γ phases of p-DCB have shown no influence of crystalline structure on stabilization products of recoil ^{38}Cl atoms. Comparison of these results with those obtained in liquid p-DCB as well as in liquid and crystalline o-DCB has led to the assumption that ^{38}Cl-for-Cl replacement in crystalline DCB occurs mainly *via* hot processes.

Investigation of chemical interactions of $^{211}Rn(EC)^{211}At$ produced astatine atoms in different media was continued in cooperation with the Joint Institute for Nuclear Research, Dubna, USSR.

Solvents with ionization potentials higher or lower than that of astatine have been found to affect strongly and in opposite directions the hydrogen- and chlorine replacement in chlorobenzene. As is shown in *Fig. 3* addition of triethylamine (TEA) having a lower ionization potential than astatine, increases ^{211}At-for-Cl replacement yields up to 60% of the total activity. This phenomenon may also be important in the preparation of ^{211}At-labelled compounds.

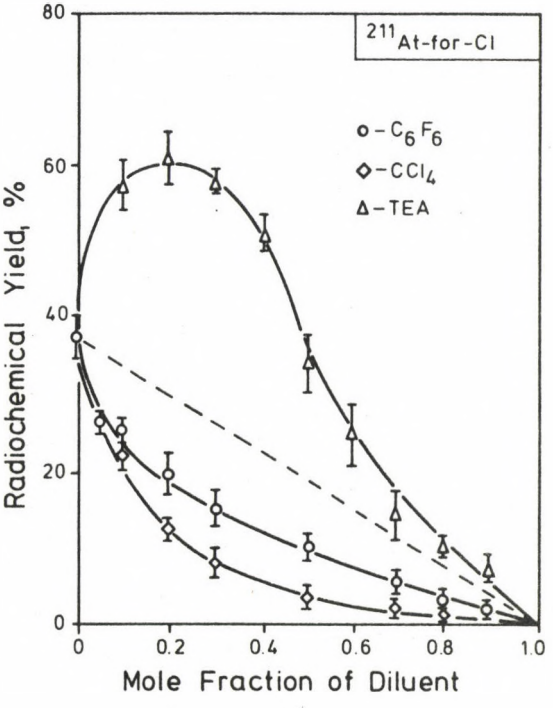


Fig. 3
Effect of dilution on the ^{211}At-for-Cl replacement in liquid chlorobenzene

Isomers of astatonitrobenzene have been synthesized; some of their properties and separation conditions have been studied by means of GC and HPLC. We used the method of GC retention indexes to estimate the boiling temperatures of o-, m- and p-$C_6H_4AtNO_2$.

The same method was used to evaluate the boiling temperature and enthalpy of vaporization in a series of organic astatine compounds: o-, m-, p-C_6H_4AtX (X = H, F, Cl, Br, I, CH_3).

An experimental technique for measuring bond energies in tracer amounts of volatile organic halogen compounds has been developed and utilized to determine the C-At bond energy in astatobenzene, n- and i-propylastatide.

The investigations into the chemical and physical properties of bridged ferrocene derivatives were continued in cooperation with the Brookhaven National Laboratory, Upton, NY, USA. Keto derivatives of hetero- and homoannularly bridged ferrocenes *(Fig. 4)* were prepared and

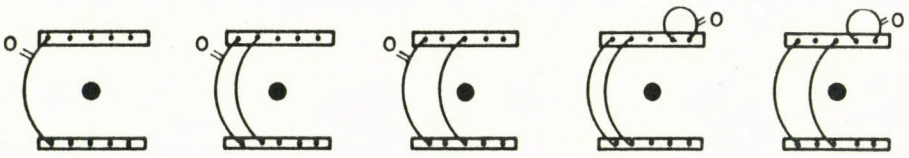


Fig. 4

α-keto derivatives of hetero- and homoannularly bridged trimethylene ferrocenes. In each case the rectangles, the small solid circles, the large solid circle and the arcs represent the cyclopentadienyl rings, the carbon atoms of the ring, the iron atom and the trimethylene groups, respectively

investigated by Mössbauer spectroscopy and cyclic voltametry. A strong electron withdrawing effect was found in the case of α-keto derivatives of bridged ferrocenes by measuring the oxidation potentials. The electron withdrawing effect (EWE) depended on the position of the keto group in relation to the cyclopentadienyl ring. For bridged ferrocene compounds containing a keto group in the β-position, a decreased EWE was observed. The α-keto group of the homoannular bridges showed an EWE which was usually higher than that of the hetero bridge.

PUBLICATIONS: 230, 336, 337, 338, 406, 407, 469, 484, 582, 666, 677, 668, 669

RADIATION AND ELECTRON CHEMISTRY

Gy. Hutiray, Inna Kules, L. Nyikos, T. Pajkossy, Magdolna Roder, R. Schiller, Sz. Vass, Á. Vértes

The energy of the bottom of the conductance band in saturated hydrocarbon liquids, V_o, was expressed by the heat of evaporation and dielectric constant of the liquids. On applying the equation to 14 aliphatic compounds we found the results to agree reasonably well with the experimental data.

The kinetics of geminate ion recombination was measured by pulse radiolysis. The exact solution of the Smoluchowski equation described the time dependence adequately whereas the analytical approximations rendered correct solutions in the long time limit only. The Laplace transformation method was seen to give a good phenomenological description of the process in the entire time range studied.

The free ion yields in saturated hydrocarbons were measured as a function of scavenger concentration by pulse radiolysis and the results were compared with existing theories.

The existence of highly mobile negative charge carriers in liquids like C_6F_6 and CS_2, where the electrons are attached to matrix molecules, was observed by pulse radiolysis and microwave conductivity and the mobilities were measured both in pure liquids and in mixtures. As a mechanism, negative ion-molecule charge transfer was suggested. The pulse radiolysis studies were made in the Interuniversity Reactor Institute, Delft, The Netherlands.

Quantum chemical CNDO/2 calculations were performed in order to check the possibility of charge transfer between positive or negative ions and the corresponding molecules. A high Franck-Condon factor for the transfer was found with molecules which were prone to fast positive or negative charge transport in the liquid state.

Charge transport in liquid mixtures where the mobile state of the carriers can form only if the charge is surrounded by the molecules of one component alone was treated in terms of percolation theory. Considering concentration fluctuations and applying effective medium expression, the concentration dependences of both electron and positive hole mobilities were calculated (e.g. *Fig. 5*).

Based on certain ideas of continuous time random walk theory, percolation in fluctuating systems was treated and an expression found for the percolation limit, $c_c\ [(e-1)/Ne]^{1/2}$, where N is the coordination number of fluctuating subsystems and e is the base of the natural logarithm.

The rate constants of bimolecular reactions and the two particle correlation functions of the reactant molecules were expressed in terms of an equilibrium collision model. By this the difference between the rate constants for reactions in aggregated (e.g. micellar) and non-aggregated systems can be understood.

A stochastic formalism for the description of the kinetic processes in aggregated systems was shown to render results which are different from those obtained through conventional kinetics.

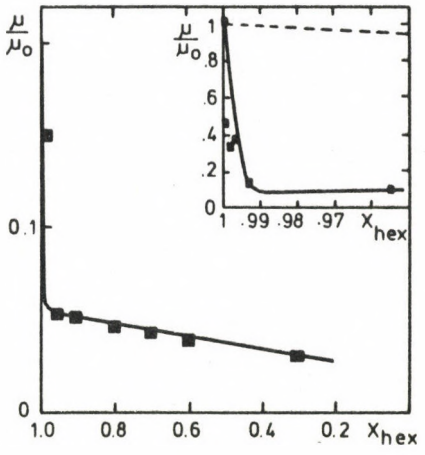


Fig. 5

Dependence of relative mobility (μ/μ_o) on mole fraction (X_{hex}) in n-hexane - ethanol mixtures. ■ : Experimental data (G. Beck and J.K.Thomas, J.Chem.Phys. 57, 3649 (1972)). Solid line: theoretical curve. Inset: low ethanol concentration portion

The steady state and the transient photoelectrochemical behaviour of thermally grown semiconducting iron oxide were studied under various conditions using rotating disc electrodes. The results were interpreted in terms of a competition between hole injection from the valence band and hole recombination through surface states. Current saturation with high light intensitites and basic features of the phototransients can be understood by considering the photoresponse of the semiconductor space charge layer.

Thin WO_3 layers and sodium-tungsten bronze single crystals were prepared and their photoelectrochemical and electrochromic properties studied under various conditions. A correlation between voltage controlled electric and optical transients was observed and attributed to H^o transport into the solid. The diffusion controlled kinetics of this process was investigated.

Preliminary experimental studies were carried out on activity transport in the primary circuit of atomic power stations. Suspended contaminations in the boiler-water of conventional thermal power stations were analysed by chemical composition, particle size, and by their ability to be activated by neutrons; the results obtained were compared with the physical and chemical properties of the depositions on metal surfaces.

The radiation stability of chloride-selective electrodes was studied and the electrical response was found to be virtually unchanged with doses not higher than 45 Mrad. Work on this topic was carried out in conjunction with the Khlopin Institute, Leningrad, USSR.

PUBLICATIONS: 195, 265, 296, 297, 298, 299, 300, 339, 340, 588, 589, 619, 662, 670, 671

RESEARCH INSTITUTE
FOR MEASUREMENT
AND COMPUTING
TECHNIQUES

DEVELOPMENT OF CAMAC MODULES AND SYSTEMS

L. Almási, J. Biri, M. Blasovszky, P. Bördén, N. Buchmüller, P. Giese, Gy. Kertész, I. Mohos, T. Nemes, J. Rehó, J. Sarkadi, Katalin Somlai, L. Somlai, Gy. Stancsich, Gy. Vashegyi, Zs. Zárándi, K. Ziegelmann

We have continued the development and production of measuring equipment in CAMAC and its application to various fields. We designed and produced a number of new CAMAC modules. In order to increase the application possibilities of our complete systems either more special purpose modules have been developed or some of the formerly developed ones modernized.

The intelligent system based on the INTEL-8080 microprocessor elaborated during the previous years has been expanded with low power and big capacity PROM and RAM memory modules of 16K, 48K and 64Kbyte capacity, some of them with battery back-up.

In addition, we have developed the basic module set of a completely new 16 bit intelligent system using the LSI-11 microprocessor.

As a general purpose unit an alphanumeric-graphic display driver was developed for colour TV monitors. This display driver permits simultaneously two spectra (histograms) each with 256 dots in one of the R-G-B colours or in their mix. In the vertical direction the resolution is 256 steps too. It is also possible to generate alphanumeric patterns. The full picture contains 32 lines - 64 characters each line - on the screen.

Besides the development of hardware units, advances have also been made in CAMAC operating software. To satisfy the software requirements of the microprocessor driven system a special new BASIC interpreter was prepared, to run under the control of the DOS-80 operating system.

Last year, a highly complex measuring system was installed at the I.V. Kurchatov Institute of Atomic Energy, Moscow, USSR: a measurement automatization system for data collecting and evaluating of the plasma diagnostics of the T-7 tokamak. This system contains a TPA-i machine with 24K words operative memory, 256K words disc memory, magnetic tape backing stores, three intelligent CAMAC systems and an on-line operated multichannel analyser having 4K/16 bit memory. The system

measures and evaluates 110 analogue and 40 digital signals of the electromagnetic diagnostics, soft and hard X-ray diagnostics, corpuscular diagnostics, Thomson scattering, bolometric diagnostics and submillimeter interferometry for the plasma.

PUBLICATIONS: 131, 132, 255, 364

INDUSTRIAL APPLICATIONS OF SMALL COMPUTERS

L. Kerényi, Gy. Mikóvári, Z. Paddnyi, Z. Stéger, Gy. Vashegyi

One of our major concerns, in the Department of Industrial Applications, has for some years involved the computerization of industrial process control systems and a number of such systems have been realized in various fields of application. One of these, installed at the Danube Oil Refinery Station, is a computerized control system for filling rail containers.

The background to this is that the Danube Oil Refinery Station bought filling equipment from the firm Claudius-Peters of the FRG for the railway transportation of several hundreds of thousands of tons of liquids per year. We were involved in this venture as a subcontractor of the German firm. We installed the computerized control system of the filling equipment which was in fact one of the first computer controlled filling devices of the firm Claudius-Peters, though this organization is specialized in the production of different filling and transporting technologies.

The computerized control system has enabled filling to work fully automatically (with the supervision of just one operator). The two main operating stages are as follows: the rail containers are simultaneously positioned on adjacent tracks and the system then initiates filling - as required -: two kinds of gas-oil and three kinds of gasoline through 3 filling tubes per container with the accuracy of 0.1-0.2% (and it registers and invoices every 20 kg).

The control functions are performed by Intelligent Crate Controllers via algorithms burnt in PROM memory. The controlling ICCs are extended with a TOA-S configuration - being on-line with them and having the peripherals: floppy disk, display, and matrix printer. This configuration performs all administrative work related to the operation of the filling station.

PUBLICATION: 420

DEVELOPMENT OF SMALL COMPUTERS

Gy. Balatoni, F. Báti, B. Biró, T. Bozsó, A. Csákány, E. Hamza, L. Joó, J. Kántor, Róza Kertes, G. Komlós, I. Kővári, G. Lőrincze, M. Marton, Z. Nyitrai, P. Patóh, J. Sulyán, P. Szabó, Gy. Tamás, Katalin Tarnay, T. Török, Klára Varga

High-performance computer systems are needed to back-up our industrial, laboratory and business applications. With this in view, the TPA 1140 system has been extended with a fast cache memory, several new mass memories and communication peripherals.

The peripheral and formatter units (developed for the TPA 1140) enabled MOM's floppy disk to be approved in the Socialist Countries' Mini Computer System.

Particularly worthy of mention is the fast, small computer oriented magnetic tape unit which might become the first device in this category, developed in the socialist countries.

Our fields of application have also been extended. In the framework of the reconstruction of the electrical industry - in cooperation with experts of the Telecommunication Research Institute, Budapest - we have installed systems for designing and documenting printed circuit boards.

In the framework of the bubble memory program an ICC (Intelligent Crate Controller) based programmable device for bubble memory test was worked out. This device is suitable for long-term parametrical testing and for "go no-go" testing as well.

Last year two important events occurred in the field of data networks and data processing:

The Network Theory School organized by our Institute became a recognized authority of the Hungarian specialists. The many-sided, very adaptable program system for network simulation - the NETSY - was completed. This is very useful for basic research and in the measurement of networks.

In education, we continued with the production of "Courseware". A number of preprints were published. A program system has been completed which makes possible the computerized simulation of the whole system of public education. An example of such a simulation is: "The examination of the effects of over-education in industry and in education".

PUBLICATIONS: 32, 33, 34, 330, 365, 366, 367, 425, 426, 517, 550, 644, 645, 646, 656

APPLICATION OF MICROPROCESSORS

G. Ambrózy, F. Báti, G. Bóna, S. Ebergényi, I. Erényi, L. Leveleki, Magdolna Lovászi, J. Miskolczi, I. Rényi, L. Sándor, L.T. Sándor, I. Szabó, M. Szalay, F. Vajda

In recent years the already developed microprocessor based computers - TPA-L and EMU-11 - have been used in several fields of application. The TPA-L's are primarily utilized for business purposes, the latter machines in scientific-technical systems.

A faster version of TPA-L and the memory management unit of the EMU-11 are currently under development.

The Universal Microprocessor-Development System (UMDS) has been extended by a new type, floppy-disk based operating system.

"In-circuit" emulator modules have also been elaborated for developing 8080 and Z80 microprocessor systems.

The debugging environment programs of the system have been written and the first users have already put these development systems into operation *(Fig. 1)*.

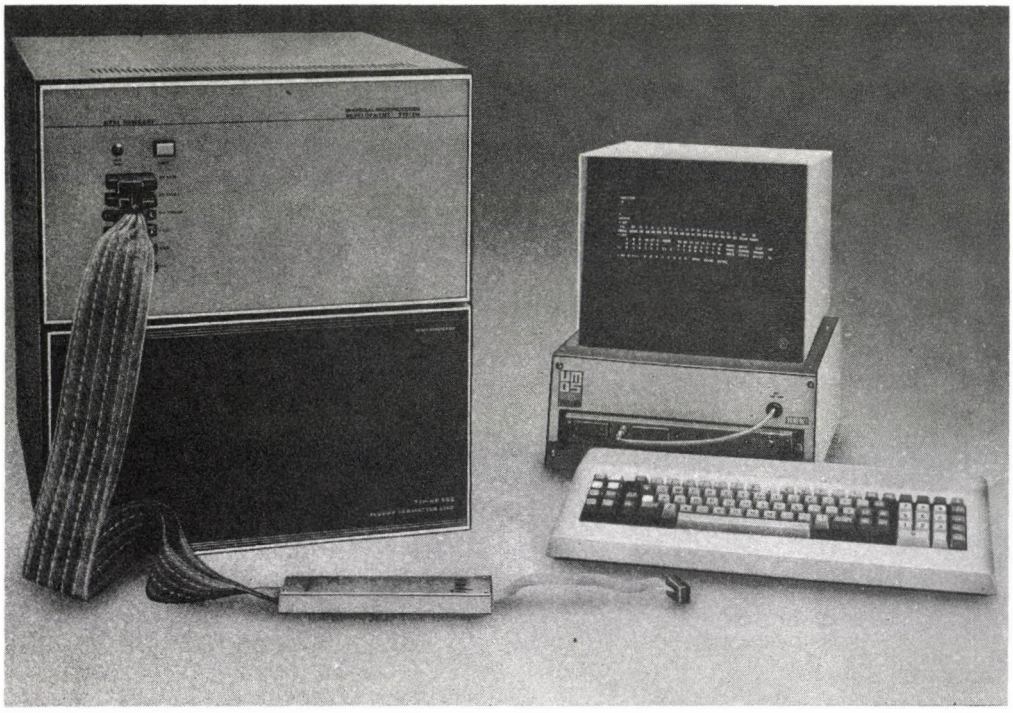


Fig. 1

Universal Microprocessor Development System (UMDS) with the Universal Display Terminal (UDT)

We have worked out an 8080 microprocessor based programmable display terminal (Universal Display Terminal) in two versions for use in the TPA-8 and TPA-11 computer families. The programmable display terminal enables different communicational protocols to be handled simply by changing the relevant firmware. The emulator program of the VT-52 terminal specification was the first to be realized. The basic variant of the microprocessor based display terminal is complete with regard to both software and hardware.

For special picture-processing tasks, we have developed a microprogrammable processor, based on the AM 2900 series bit-slice elements.

PUBLICATIONS: 9, 10, 19, 57, 101, 102, 145, 284, 285, 333, 368, 369, 612, 657, 658

TECHNOLOGICAL RESEARCH

M. Bak, Margit Benkő, Gy. Binder, I. Borsos, B. Forgács, E. Gaál, R. Glódi, A. Hegedüs, L. Honthy, A. Jávor, A. Karacs, Gy. Révész, L. Sándor, Zs. Szabó, A. Szép, L. Szikora, A. Téby, P. Tóbiás, N. Törő, Á. Vigh

Over the last two years in the Department for Circuit Technology we have built up our mask laboratory which is designed to produce LSI masks for integrated circuit technology. The laboratory is based on an EUR step and repeat camera, made by Zeiss, and on the Soviet EM 549/B pattern generator. Further, we have a mask processing equipment CPP-8 made by CONVAC. The inspection of the masks will initially be carried out by a Zeiss NU-2 microscope system. We have developed for the laboratory a super pure water and pressurized air system, and a class 100 clean room workshop classified according to the American standards. The laboratory is capable of producing hard surface master masks up to 5" x 5" with feature size below 1.5 µm. We have begun the research work to develop and optimize the mask producing technology. Our first test masks have been completed with 1 µm elements on 2.5" x 2.5" hard chrome blanks. In 1979 we developed for our ADMAP drawing system a new, more satisfactory light spot projector called SYPRO-03 (symbol projector) which can be utilized in a larger field than the previous one. A licence for mass production of the SYPRO-03 has been sold to the FOK-GYEM Company, Hungary.

In the Department for CAD a complete system for the Computer Aided Design of microelectronic circuits has been developed. The system - called MICAD (Microelectronics Intelligent Computer Aided Design) - provides for all the basic design steps needed. Its two basic subsystems

are the LOBSTER system for digital logic simulation and design, and the DOLPHIN subsystem for the mask lay-out design.

The LOBSTER system *(Fig. 2)* is based on a mixed level simulator (taking care of time delays, transient and hazardous states, three level logics with high impedance, special MOS elements, fault simulation, etc.) and has in addition to the conventional I/O possibilities a special test-result-driven high level input language and an interactive graphic output that makes it possible for the results of the simulation to be investigated in the same way as was usual with a multitrace measuring oscilloscope.

Fig. 2
The LOBSTER System

By means of the DOLPHIN system it is possible to carry out the lay-out design, and to develop and use a library of cells. An interactive graphic design facility is also included. The system also provides for checking the design rules. The outputs provided are: control tapes for the combined control of pattern generators and step and repeat cameras, as well as for cutting rubylith foils and control drawings.

The transistor level modelling subsystem of MICAD: TRANZ-TRAN was developed in the Department of Electronic Tools at the Technical University of Budapest.

The whole system has been utilized in the design of a great number of both MOS circuits and bubble memory devices. Its subsystems are also used in a number of other institutions both in Hungary and abroad.

Results have been obtained in the field of automatic connection pattern design for LSI circuits.

PUBLICATIONS: 166, 508, 509, 510, 511

SYSTEM SOFTWARE, APPLICATIONS, AND USER SUPPORT

A. Arató, L. Buday, Katalin Burány, I. Faragó, Z. Gálfi, M. Horvai, A. Horváth, Mária Ivanyos, Éva Király, J. Kiss, R. Koch, K. Kovács, Mariann Kővári, P. Krauth, I. Mező, M. Nagy, D. Pallagi, B. Papp, Mária Rigó, M. Salamon, Éva Sándor, I. Sári, I. Sarkadi-Nagy, Teréz Sarkadi-Nagy, P. Soós, J. Szlankó, F. Telbisz. J. Telek, J. Tibor, E. Tóth

The development of system software can be divided into two areas:

- Completion and extension of basic software for the small computers developed in the Institute.

- The development of programming tools for the big computer as well as continuous support for the interactive system running on the EC 1040 computer.

The MACRO-70 macroprocessor, Magnetic Tape Handling Package, and the extension of the MINOR/D operating system have been finished for the TPA 70.

A real time monitor - the so called MINOR/COM - supporting the application of the TPA 70 in the field of communications was also developed.

Some modifications of the TPA/i Executive were carried out in order to support the application works.

The following work was completed for the TPA 1140:

- In order to improve the efficiency of our TPA 1140 configuration a new version of the DOS/RV operating system was generated and tested, RATFOR and PASCAL compilers have been implemented to aid scientific work as well as to provide users with more up-to-date programming tools.

- The implementation of a COBOL like language for business data processing has been started and several data management packages have been adapted.

- The PL-11 intermediate language compiler (received from the CERN, Geneva) has been implemented as a tool of the basic software development for the TPA 11 family and it was extended with the conditional translation facility.

- A cross system - consisting of a macro assembler, a linkage editor and a loader program - was elaborated in order to support the programming for the Intel-8080 microprocessor.

- A compiler - loader-debugger program system has been worked out to aid microprogramming.

- In the field of data-base management the design of a data manipulation package and a logical level enquiry language has been finished and the elaboration of the first versions have been started.

With regard to the ES 1040 computer, we carried out the following:

- The extension of the PL-11 cross-compiler with the conditional translation facility.

- The implementation of the cross-compiler of PL/M high level language (for the Intel-8080).

- Application of the PSA-PSL system in order to gain experience with it and check its usefulness.

- The extension and improvement of the CEDRUS interactive terminal system by providing users with enhanced job managing and status enquiry facilities as well as by completing the interactive system with several related housekeeping utility programs.

The field testing of the data acquisition system for the Szeged-Algyő (Hungary), Oilfield was finished and the system has been working successfully since the end of 1979.

The BASIC system was extended with the functions controlling an analyser coupled with an electron microscope. This system is currently working in the Research Institute for the Medical Sciences (KOKI), Budapest.

Operating systems were generated and installed for about 20 TPA 70 and 25 TPA 1140 configurations and courses were given for the users. In addition, lectures and seminars on the TPA 11 software facilities were organized, in order to promote the general knowledge of the software systems as well as to propagate their use.

PUBLICATIONS: 21, 616

DEVELOPMENT ENGINEERING

RESULTS IN THE DEVELOPMENT OF THE "BUDAPEST" ECG DIAGNOSTIC SYSTEM

S. Békési, P. Benkó, J. Bolyky, R. Hörömpő, K. Késmárky, Gy. Kozmann, A. B.Nagy, F. Szlávik, T. Wolf

The large number of heart and circulatory system diseases makes reasonable the world wide creation of computerized methods and tools for routine ECG diagnostics. During the period 1975-80 our Institute - cooperating first of all with the 2nd Internal Medicine Clinic of the Postgraduate Medical School of Budapest - has developed the "BUDAPEST" system, which could provide the basis for a computerized ECG diagnostic network.

The system has the following functions:

a) ECG archivation and retrieval.

b) Automatic computation of diagnoses.

c) Interactive processing.

The diagnostic program can recognize 34 versions of QRS, 60 versions of ST-T and 28 types of rhythm abnormalities on the basis of the FRANK lead system *(see Fig. 1)*. According to our up to date statistical tests 80% of the machine's decisions were correct, 5% were false and for the remaining 15% the algorithm gave the "non characteristic ECG wave" diagnostic statement.

At present, the hardware basis of the system is a minicomputer with 32K word core memory. Floppy and cartridge discs are used as mass background memories. The tool for man-machine interaction is a graphic display. The necessary special medical measuring system was developed in the Institute's Bioelectronic Department.

The development of a cheaper system which is portable and can thus be used at the bedside, is virtually completed. This equipment is based on the Data Terminal-8 formed from the TPA-L type minicomputer, which is extended with an analog I/O port, a graphic-alphanumeric TV raster display and some special medical measuring units.

*** 'BUDAPEST' COMPUTERISED SYSTEM FOR ECG ANALYSIS ***
****

COMP. NO.	T/R NO.	FLP/SER. NO.	DATE OF REC.	DATE
1176	23 / 51	18 / 6	800320	800409

NAME: .X...Y....
COMMENT:

****

ECG DIAGNOSIS

QRS:
POSTERO-DIAPHRAGMATICAL MYOCARDIAL INFARCTION

ST:
NORMAL

T:
LATERAL INTRAMURAL ISCHAEMIA
POSTERO-INFERIOR INTRAMURAL ISCHAEMIA

RHYTHM:
HEART RATE: 85
NORMAL SINUS RHYTHM

QRS MOMENTARY VECTORS (UNIT=0.1MV)

	1.	2.	3.	4.	5.	6.	7.	8.
X:	-0.6	0.1	7.9	14.1	2.8	-1.1	-1.7	-1.8
Y:	-0.5	-1.4	-0.3	2.1	3.3	1	0.6	-0.4
Z:	-0.2	-3.5	-6	-1.7	8.3	4.5	1.7	0.3

MEASURED VARIABLES: (UNIT=0.1MV OR MSEC)

QRS	PQ	RX	RY	MMAX	PX	PY	PZ
98	132	14.1	3.3	14.3	1.7	1.1	0.5
STX	STY	STZ	TX	TY	TZ	TY P.PER.	NO.OF CL.
-1.4	0.1	-0.4	-0.9	-1.2	-3.3	3	1

COMMENT:OK!
OVERREADER:WT
COMPUTATION UNDER SUPERVISION!

Fig. 1

Layout of the medical certificate by the "BUDAPEST" system. In addition to diagnostic statements the system also gives the important ECG signal parameters

PUBLICATIONS: 320, 371, 402

AUTOMATIC LPE CRYSTAL GROWING SYSTEM

L. Házkötő, B. Keszei, A. Rényi, G. Szabados, J. Tombor

The LPE (Liquid Phase Epitaxy) crystal growing equipment is designed to produce magnetic oxide layers for bubble memories.

The essence of the method is that a pulling head of programmable speed brings the holder containing the adequately prepared substrate crystal to a position above the supercooled melt of iron garnets in the furnace and then dips it into the melt after the stabilization of the temperature.

During the actual time of crystal growth, the substrate is rotated either in a unidirectional way or in alternating directions. After having obtained the required layer thickness, the crystal is lifted out of the melt and the liquid adhering to it is removed by centrifuging. Removal of the crystal from the furnace is also carried out at a programmed speed.

The whole system is controlled by a microprocessor. The 15 cycles of crystal growing proceed automatically (including both the transfer of the substrate and the thermal programs).

The main parts of the equipment are: three-zone vertical furnace; lift and rotation mechanism; substrate magazine; feeding unit; laminar flow box; central control unit.

The lift and rotation mechanism is driven by electromotors with adjustable rotation speed, the feeding unit by pneumatic cylinders.

The equipment *(Fig. 2)* is located in a laminar flow box.

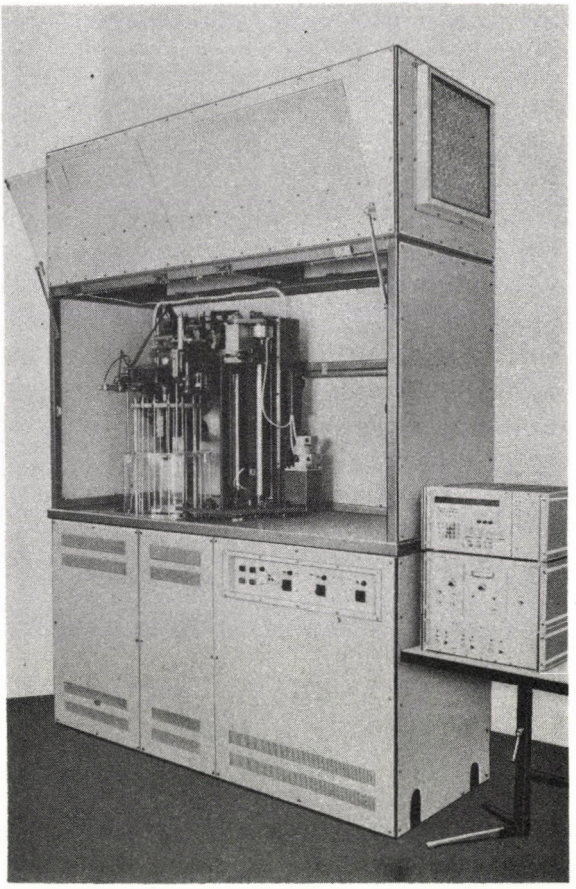


Fig. 2

Liquid phase epitaxy crystal growing equipment

Technical data:

Maximum operating temperature	1200 °C
Temperature stability	<0.2° at 950 °C
Film growth temperature	~950 °C
Maximum substrate diameter	55 mm

INTELLIGENT MÖSSBAUER ANALYSER

P. Bán, Gy. Bangó, F. Baranyi, M. Gárdos, Z. Harmathy*, J. Kőhegyi**

The Intelligent Mössbauer Analyser (IMA) is a microcomputer based data processing system which is capable of displaying the data stored in the spectrum memory, recording them on different data carriers, and of performing operations with them.

In contrast with ordinary Mössbauer analysers which are usually universal multichannel instruments, the IMA, while operating during data collection only in externally controlled multiscaler and simple amplitude analysis modes, can be programmed to carry out complicated operations for spectrum evaluation. Rather than simply displaying the spectra it also displays results of computations, programs and alphanumeric information essential for the user. The electronic parts of the Mössbauer spectrometer and the new analyser are shown in *Fig. 3*.

The intelligence of the analyser removes the burden of routine tasks which the researcher is otherwise obliged to carry out, both during and after the measurement, with the data supplied by the multichannel analyser. Moreover, it is capable of determining a few parameters which have hitherto been obtained from computer evaluation.

The programmable microcomputer is based on the so called Multi MicroProcessor System developed in our Institute. Peripherals for the system:

- cathode-ray tube raster display for alphanumeric characters, spectra and vectors by flashing the points on a 256x256 raster grid
- alphanumeric keyboard with the full ASCII character set and 20 user defined keys
- audio casette recorder for storing spectra and programs
- paper tape puncher and reader

* Department of Numerical Methods and Computer Science, Eötvös Loránd University, Budapest

- matrix printer type DZM 180 or NIP 18
- movable cursor on the display
- X-Y recorder for drawing spectra.

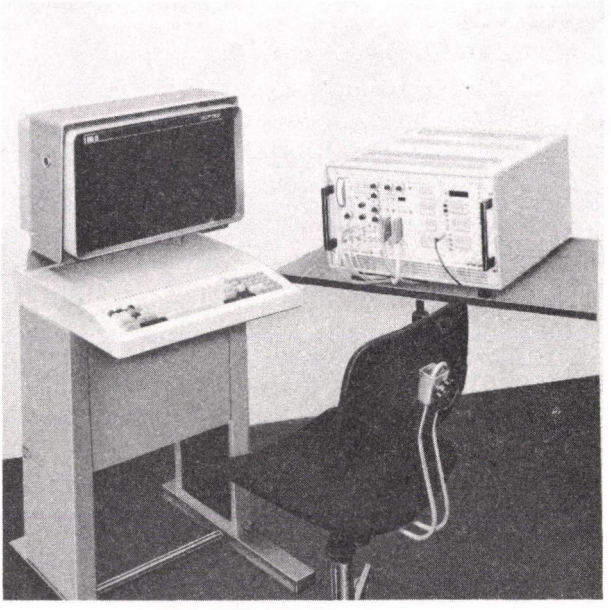


Fig. 3
Intelligent Mössbauer Analyser

The spectrum memory of the IMA consists of two memory sectors of 512 channels which can be independently filled. Each channel is 24 bits long. An interface ensures that instead of using the traditional multichannel analyser the IMA can be controlled by the Velocity Controller. To control the discrimination level of the single channel analyser and to drive the X-Y recorder, an analogue signal of 0.1% resolution is produced. The instrument can be connected to other computers through a serial asynchronous line. A built-in real-time clock serves for setting the measuring times.

Using the hardware listed above, the IMA can be programmed in a kind of BASIC which has been developed in our Institute and is a variation of the CAMAC BASIC. Separate subroutines written in assembly language serve for displaying and shifting of spectra, determining and displaying parameters, setting the measuring time, etc. All operations on spectra (calibration, derivation, integration) that are everyday tasks from a physicist's point of view can be performed.

PUBLICATION: 399

AUTOMATIC DIFFUSION BOAT PUSHER/PULLER

B. Fialovszky, J. Perendi

This equipment *(Fig. 4)* has been developed for research into ion-implanted integrated circuits.

The developed system realizes the periodic, reproducible insertion and extraction of wafers to be soaked at different speeds in the diffusion furnace by hydropneumatic operation and electronic control, so the required circuit-figures are produced on the silicon slides by way of oxidation or diffusion.

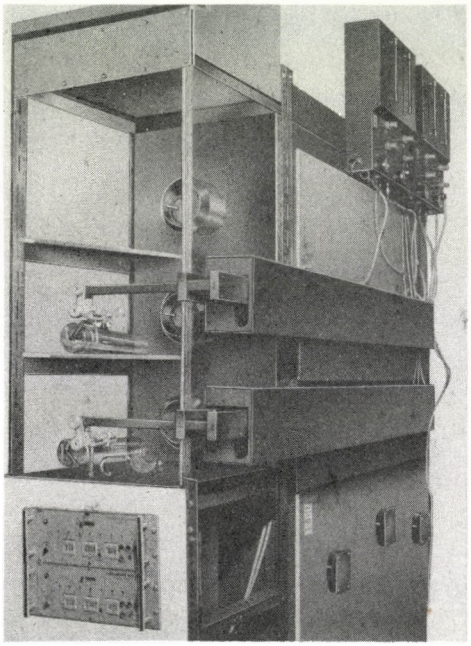


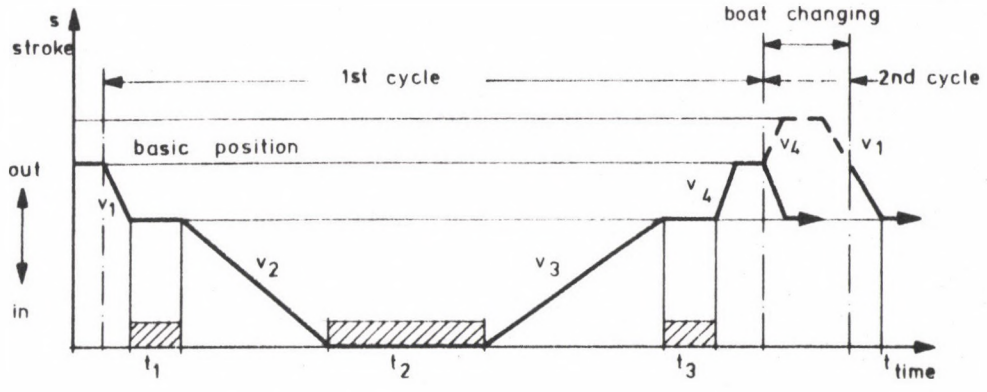
Fig. 4
Automatic Diffusion Boat Pusher/Puller

Parameters can be adjusted as follows:

- Speed of periodical push and pull (v_1, v_2, v_3, v_4, by throttles built in the hydraulic circuit)
- Period of soaking (t_1, t_2, t_3)
- Position of soaking (by some movable electric position switches).

The running down of heat treatment of the wafers fed in the boat proceeds automatically *(Fig. 5)*; however, if necessary it is possible to

intervene in the program at any time (manual control). The movement of the boat, and its instantaneous position can be followed on the electronic control unit.



v_1, v_2, v_3, v_4 adjusted speeds
t_1, t_2, t_3 periods of soaking

Fig. 5

Complete cycle of soaking

In case of power-shortage, the boat is returned to the basic position by the pneumatic system.

The mechanical part of the boat movement can easily be mounted on the outside of the furnace.

Specification:

Max. stroke	1000 mm
Speed	0.5-20 mm/s (adjustable)
Gears	2
Diameter of quartz rod to be clamped	~12 mm
Periods of soaking	t_1, t_3: 0-100 min
(adjustable)	t_2: 0-1000 min
Pneumatic power	5 bar, ~50 ℓ (S.T.P.)/min
Electrical power	220 V, ~70 VA

SHOCK AND VIBRATION ISOLATOR FOR SPACE RESEARCH INSTRUMENTS

G.T. Endrőczi, M.F. Ránky

Various kinds of measuring devices have been developed for space research by our Institute within the scope of the Intercosmos Programme.

Structural design, protection against shock and vibration at launching and during the space flight, together with the testing methods utilized are all fundamental steps for successful operation.

A characteristic example of this work was to develop a means for shock and vibration isolation of thermoluminescent dosimeters (TLD), for space research. In order to protect the photomultiplier tube within the TLD against excessive shock and vibration a special container, a 3-dimensional isolator of frictional principle, was designed *(see Fig. 6)*. This container was tested for a given shock and continuous sinusoidal excitation; the corresponding response curves are shown in *Fig. 7*.

The TLD and the container operated well during the joint Soviet-Hungarian manned space flight.

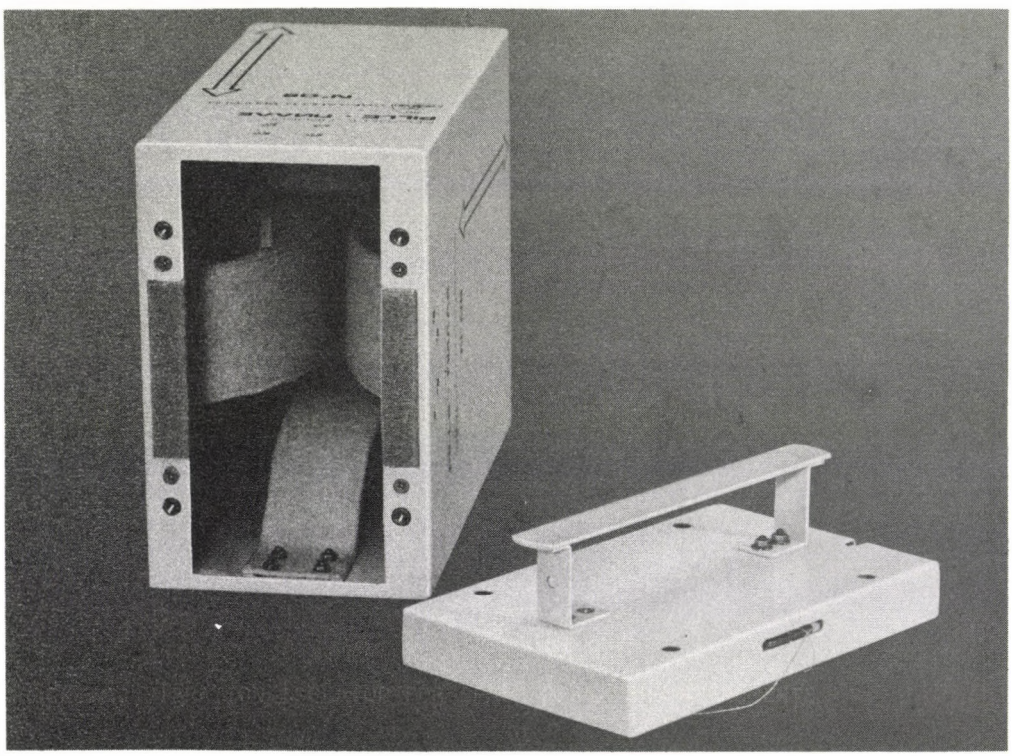


Fig. 6

Container for shock and vibration isolation

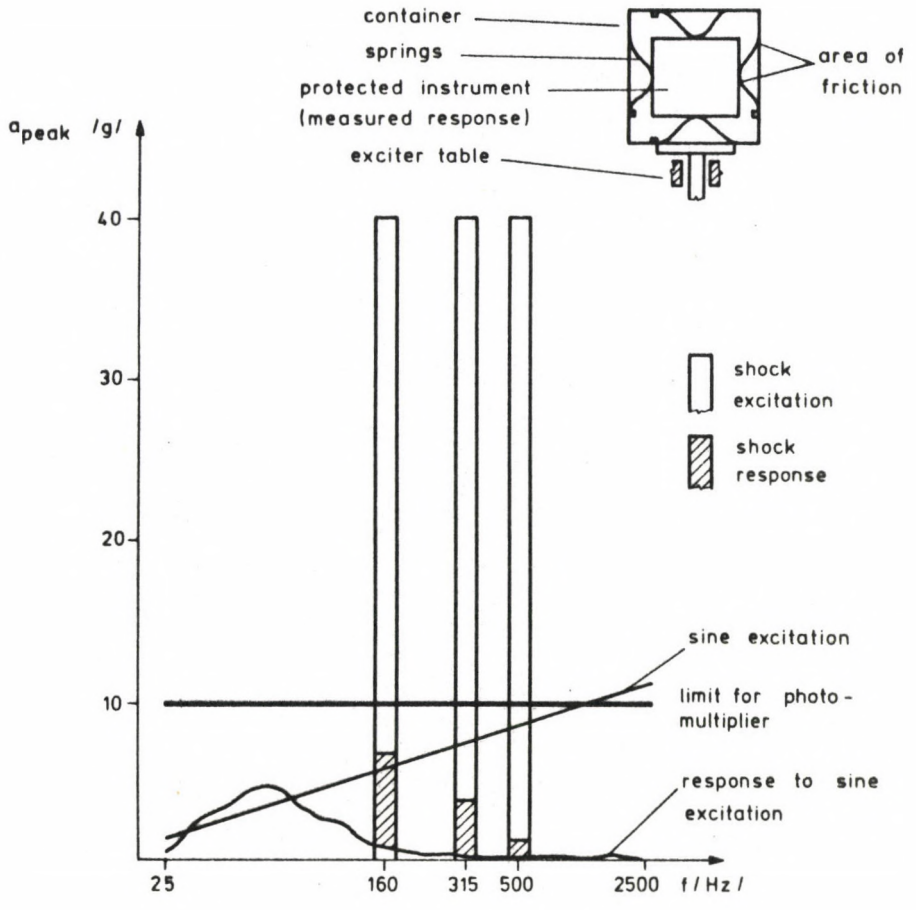


Fig. 7

Response curves for external excitation of isolator

PUBLICATION: 456

COMUPUTING
CENTRE

USER'S SUPPORT

A. Arató, K. Bándti, T. Benkő, Magda Bodnár, Zs. Dobolyi, J. Frank, T. Gaál, Irina Gladkikh, Erika Lovas, Livia Major, A. Nagyházi, I. Sarkadi-Nagy, Katalin Szalay, F. Telbisz, Judit Vámos, Éva Vass, Magda Zimányi

The Computing Centre of the Institute has operated the following computer configurations:

- ES 1040 computer equipped with 1 Mbyte core memory, 24 exchangeable disk units (2.75 Mbyte/unit), 8 magnetic tape decks, slow peripheral units and a plotter device.

- An interactive system which consists of a TPA 70 minicomputer with 28K words core memory as a front-end processor, 17 display units (two of them are remotely located), two matrix printers and paper tape I/O units.

The ES 1040 configuration was extended in the last quarter of 1980 by a BASF disk controller (type: 6015) and 8 BASF disk units (type: 6215, 60 Mbyte/unit).

With regard to the installation of the BASF disks, three hardware and two software specialists have received special training in West Germany.

A further facility is added to the services as an enhancement: Any interactive terminal can be used as an operator's console of the ES 1040 computer (one of them is permanently used as the master console).

The enlargement of the ES 1040 configuration by BASF magnetic disks needed a newly generated operational system. This new system corrects some errors of the previous one and offers better chances for effective operation.

The CEDRUS interactive terminal system that was developed in the Institute, has been working for about 96% of the service hours of the computer since the third quarter of 1979.

About 65% of the jobs are now submitted via the CEDRUS system. At present, the monthly average of jobs is 5000 as against the earlier 3100 jobs/month.

In order to increase the computer system's efficiency, several hardware modifications have been introduced. The hardware specialists have developed a control unit to facilitate off-line plotting by using magnetic tape input instead of punched tape.

The program library has been considerably extended. Now the IMSL (International Mathematical and Statistical Library) subroutine library, IBM's SL-MATH subroutine library and the FORTRAN H Extended compiler are available to users together with the CERN Library and the CPC (Computer Physics Communications) Program Library.

Several manuals have been compiled to help users of the Computing Centre.

PUBLICATION: 439

COMPUTER SCIENCE AND APPLIED MATHEMATICS

G. Ács, S. Doleschall, Éva Farkas, Borbála Gellai, Cs.J. Hegedüs, Gy. Lőcs, G. Németh

Studies on the formal description of programming language semantics have been continued. Investigations were carried out on the architecture and programming of non-Neumann computers.

The computation of the intra- and intermolecular frequency distributions have been completed for the isotopic water molecules H_2O^{16}, D_2O^{16}, T_2O^{16}, H_2O^{17}, H_2O^{18} by using the Monte-Carlo method. The vapour pressure isotope effect has been calculated for the above mentioned water molecules as an excellent test of the effect of intermolecular forces on the motions of molecules in the condensed phase. The results underscore the importance of detailed consideration of all degrees of freedom in the condensed phase.

New versions of conjugate direction algorithms have been developed for solving systems of linear equations. The structure of the inverse of tridiagonal matrices has been fully given by generalizing a theorem of Barrett and the theorem of Gantmacher and Krein.

A versatile PL/1 program has been developed for simulating isothermal processes in underground oil reservoirs. The program is built up modularly and is capable of treating different cases as regards the number of phases and components, the dimensions and the type of coordinate system. This program has been successfully applied in predicting the performance of the Lovászi-West Oil Field, Hungary.

PUBLICATIONS: 150, 151, 256, 269, 270, 467, 468, 512

SYSTEM SOFTWARE

Gabriella Békési, Zs. Dobolyi, J. Frank, T. Gaál, Irina Gladkikh, Ilona Kaposi, Erika Lovas, Katalin Szalay, G. Turchányi, Judit Vámos, Éva Vass, Magda Zimányi

Some programs have been completed that facilitate operator's work, system maintenance and the keeping of records of disk and magnetic tape volumes.

A program package has been developed for measuring system throughput, job turnaround time and use of system resources. The package processes SMF (System Management Facilities) data collected by the operating system. Statistics produced by the package supports the Computing Centre management in pinpointing system bottlenecks and the improvement of system performance.

The procedure library has been revised following the enlargement of the ES 1040 system and numerous easy-to-use procedures have been introduced in order to facilitate the work of the computer users.

PROGRAMMER'S AIDS

Zs. Dobolyi, T. Gaál, Irina Gladkikh, Ilona Kaposi, Katalin Kulcsár, Erika Lovas, G. Turchányi, Magda Zimányi

During recent years there has been a steady effort to improve efficiency. Languages have been adapted and application packages developed. It is true that some of these proved to be of little real benefit, but there was, however, a gain in valuable experience. The following languages have been installed and tested:

PASCAL compilers have been available since 1979. They are rated highly by users and they have a promising future.

The FORMAC language (preprocessor and run-time package) was installed on the ES 1040 computer. FORMAC (FORmula MAnipulation Compiler) provides the symbolic manipulation of mathematical expressions; e.g. the expression SIN(X) can be differentiated, resulting in the expression COS(X). In general, expressions can be differentiated, evaluated, replaced, compared and parsed.

The FORMAC and the REDUCE2 formula manipulation languages have been used for solving problems in theoretical physics and mathematics.

The PROLOG language yields another possibility for solving non-numerical problems.

RATFOR and MORTRAN are FORTRAN preprocessors for improving FORTRAN (structured programming tools, extended instruction set, simple I/O and macro-like facilities).

The CDL2 high level language for software development purposes (installed by courtesy of SZÁMKI, Budapest), serves as a base for implementing ADA, a high level programming language.

The ISDOS PSL/PSA system (originating from Michigan University, Ann Arbor, Mich., USA) describes and analyses information processing systems. Two new versions of the monitor of ISDOS for OS MVT and MFT systems have been developed. These versions do not require HASP facilities, but they are based on special routines that are useful in other cases of monitoring programs written in high level programming languages.

AGAR (inventory management and control system) was elaborated in 1978. In the past two years the system has been used successfully in practice. It consists of several data processing subsystems. The major part of the subsystems is written in a specific interpreter language developed for this purpose.

PUBLICATIONS: 125, 133, 221, 427, 428

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2. G. AIKHNER* et al. (including GY. VESZTERGOMBI, D.D. KISS, I. MANNO, E. NAGY, L. SZENTE, L. URBÁN): Poisk ocharovannykh chastits v neitronnom puchke na serpukhovskom uskoritele. Yad. Fiz. 29, 94 (1979)

3. D. ALBRECHT* et al. (including J. ERŐ, Z. FODOR, I.HERNYES, Z.SERES): Large-angle quasi-free scattering in ^{6}Li(p,dp)^{4}He at 670 MeV. JINR Preprint EL-12727 (1979)

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5. K.F. ALBRECHT* et al. (including I. MANNO, L. URBAN, G. VESZTERGOMBI): K_L^0-K_S^0 transmission regeneration on deuterons and neutrons in a momentum range of 10-50 GeV/c. Nucl. Phys. B 158, 29 (1979)

6. M.G. ALBROW* et al. (including G. JANCSÓ): pp collisions with a high p_T charged hadron trigger at the CERN ISR. Physica Scripta 19, 99 (1979)

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