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DEPARTMENT OF THERMONUCLEAR RESEARCH
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Edited by
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Department of Thermonuclear Research Annual Report 1990 presents the most important results of theoretical, experimental, and technological studies, carried out within a framework of two programs: Diagnostics of High-Temperature Plasma (CPBP 01.10) and Nuclear Technology (CPBR 5.8). Theoretical studies of tokamak edge plasmas, charged particle motions, strong refraction effects, current pulse generators, classical models of atomic collissions, and electron mechanisms of the Coulomb barrier tunneling, are shortly summarized. Experimental studies of X-ray, ion, and proton emission from the RPI-type devices, as well as optimization tests and electron beam measurements at the PF-type facilities, are described. Technological studies of opto-electronic transmission systems, modifications of diagnostic equipment, design and construction of new PF facilities, as well as applications of the IONOTRON-type devices, are also presented.

Raport Roczny 1990 Zakładu Badań Termojądrowych przedstawia wyniki badań teoretycznych, eksperymentalnych i technologicznych, przeprowadzonych w ramach dwóch programów badawczych: Diagnostyka Plazmy Wysokotemperaturowej (CPBP 01.10) i Technologia Jądrowa (CPBR 5.8). Krótko podsumowane są badania teoretyczne plazmy przyściennej w tokamaku, generatorów udarów prądowych, klasycznych modeli zderzeń atomowych oraz elektronowego mechanizmu efektu tunelowego. Opisane są badania eksperymentalne emisji promieniowania X, jonów i protonów z układów typu RPI, a także próby optymalizacji i pomiary wiązek elektronowych na układach typu PF. Przedstawione są również badania technologiczne układów opto-elektronicznych do transmisji danych modyfikacje wyposażenia diagnostycznego, projekty i konstrukcje nowych układów typu PF oraz prace nad zastosowaniem urządzeń typu IONOTRON.

Рапорт за 1990 г. Отдела Термоядерных Исследований представляет основные результаты теоретических, экспериментальных и технологических исследований проведенных в рамках двух исследовательских программ: Диагностика Высокотемпературной Плазмы (CPBP 01.10) и Ядерная Технология (CPBR 5.8). Коротко описаны теоретические исследования пристеночной плазмы в токамаке, генераторы ударов тока, классические модели атомных столкновений и электронных механизмов тунельного эффекта. Описаны экспериментальные исследования эмиссии рентгеновского излучения, ионов и протонов из установок типа RPI, а также исследования оптимализации и измерения электронных пучков из установок типа PF. Представлены также технологические исследования оптоэлектронных систем трансммисии данных, изменения диагностического оборудования, проекты и конструкции новых установок типа PF и работы по применениям установок типа IONOTRON.

CONTENTS

1. PREFACE

by M.Sadowski

In 1990, the main activities of the Department of Thermonuclear Research /P-V/ at the Soltan Institute for Nuclear Studies (SINS) in Świerk, Poland, were concentrated upon the continuation of previous research projects [1]. Theoretical and experimental studies were carried out within a framework of two programs: Diagnostics of High-Temperature Plasma (CPBP 01.10) and Nuclear Technology (CPBR 5.8), and additionally under special industrial and export contracts.

Theoretical investigations concerned behavior of tokamak edge plasmas, motion of charged particles, analysis of strong refraction effects, simulation of current pulse generators, studies of atoms alignment in external magnetic and electric fields, and hypothetical electron mechanisms of the tunneling effect.

Experimental studies were concentrated upon characteristics of the X-ray and ion emission from the IBIS multi-rod plasma injector, optimization of plasma-focus (PF) discharges in different facilities (MAJA-PF, PF-360), development of a new diagnostic equipment, and magnetic control of plasma discharges in the SOWA-400 cylindrical facility.

Technological investigations were devoted to final design and tests of a multichannel opto-electronic transmission system, design and construction of new PF facilities, construction and tests of the SOWA-1000 vacuum chamber, and applications of the IONOTRON-type devices to the modification of solid surfaces. Additional efforts were connected with design and tests of a laboratory facility for the production of miniature cryogenic pellets for hot plasma experiments.

Some studies mentioned above have been performed within a framework of the scientific cooperation with other departments of SINS in Świerk, with the Institute of Plasma Physics and Laser Microfusion in Warsaw, with the Institut für Plasmaforschung (FRG), and with the Kurchatov Institute of Atomic Energy in Moscow (SU).

2. THEORY AND COMPUTATIONAL PHYSICS

2.1. Analysis of Physical Model and Boundary Conditions for Nonlocal Transport Coefficients of Tokamak Edge Plasma

(CPBP 01.10.01.2.2)

by M.Rabiński

The BOUND1D package of one-dimensional codes, that was developed for analysis of tokamak edge plasma and neutral gas [1], has been improved by introducing a more sophisticated model of the plasma transport with nonlocal heat fluxes and viscous stresses [2,3]. Equations describing the transport coefficients have been taken from the Igitkhanov & Yushmanov paper* basing upon the Grad approximation. For the boundary conditions a requirement has been assumed that the hydrodynamic moments are equal to the kinetic ones at a divertor plate. Nevertheless, computational studies carried out with the model described above have showed that the applied description of nonlocal coefficients leads to irrationally large values, which destabilize subsequent calculations [2,3].

Critical analysis of the obtained results made possible to find several mistakes and unmotivated simplifications in the equations used by Igitkhanov & Yushmanov*. A new, improved model for nonlocal heat fluxes and viscous stresses has been developed**. Equations describing the considered problem have been derived within the framework of the 21-moment Grad approximation, on the basis of general formulae given by Zhdanov for a multicomponent plasma***. At the moment, some new computational studies are carried out in order to investigate influence of so-defined nonlocal coefficients on the edge plasma transport.

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* Yu.Igitkhanov, P.Yushumanov: Contrib. Plasma Phys. 28 (1988) 4/5, 341-344.

** M.Rabiński: submitted for the 18th Conf. on Controlled Fusion and Plasma Physics, Berlin 1991.

*** V.M.Zhdanov, "Transport Phenomena in Multicomponent Plasma" (in Russian), Energoizdat, Moscow 1982.

2.2. Study of Charged Particles Motion within a Steady Current Filament (CPBP 01.01.03.1.1)

by W.Frejlak and M.Sadowski

In the most simple model it is usually assumed that a cylindrical steady current column is quasineutral electrically, and the only macroscopic field is the azimuthal magnetic field connected with the considered current filament. If a mean free path of ions is long enough in comparison with a plasma diameter, one can get important information analyzing motion of individual charged particles within the given macroscopic field. Such an analysis has been performed, e.g., for a regular system of parallel current filaments*.

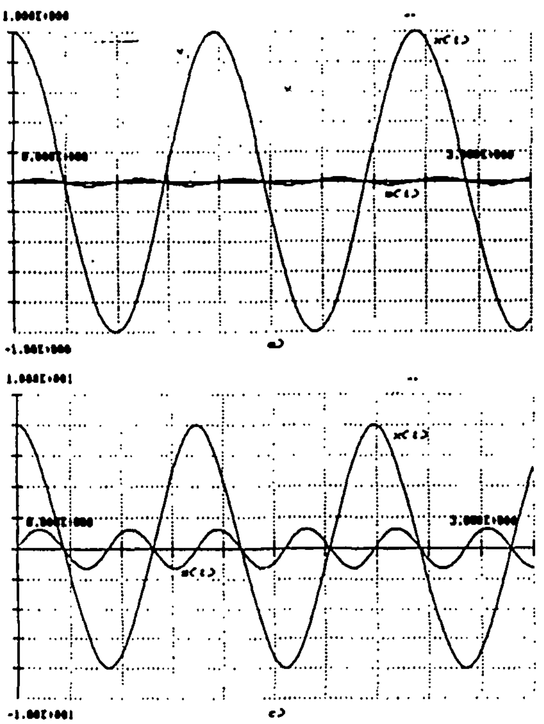

Fig.1. Trapping and acceleration of deuterons starting from different points inside the current filament [4].

In order to analyze filament with a steady current, a new model has been developed. It has been noted that electrical quasi-neutrality of the whole filament does not exclude existence of radial electrical fields inside a plasma. Taking into account the Hall effect, connected with electrons which can occupy a cylindrical volume with a radius smaller than that of heavier ions, numerical calculations have been performed [4] for different physical parameters and various initial conditions, as shown in Fig.1.

The results of this theoretical analysis, taking into account the Hall effect within the plasma column, show that plasma filaments characterized by a high velocity electron drift, can form relatively effective traps of positive ions.

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* W.Frejlak, M.Kowalski, and M.Sadowski: Proc. Plasma'88 Symposium, Jachranka 1988, Vol. 2, p.203.

2.3. Development of Stand for Computer Analysis of Experimental Data (CPBP 01.10.03.1.1)

by K.Przybylski

A computer stand designed for analysis of experimental data, which are registered with photographic films, has been modified and tested [5]. Registered pictures can be transmitted to an IBM-PC through a standard TV camera (Vidicon or CCD type) and an appropriate scanner card.

An integrated TRANS_DIG program package, version 3.0, makes possible to introduce the pictures into an operational memory of the computer, to store the digitized pictures in the data basis, to convert these pictures, and to perform their graphical and statistical processing in order to obtain appropriate functions corresponding the waveforms registered with oscilloscopes.

In the previous versions of the TRANS_DIG programs [1] instead the scanning card use was made of the TV52 digitizer. The main disadvantage of that configuration was a relatively long time of the data transmission through a series connector (the maximal transmission capability was 9600 bouds). The replacement of the digitizer by the internal TLP-640 scanner card and some changes in the program package have considerably improved the operation of the system. The processing time for the pictures registered has been shortened by about 70%.

A picture from the camera can be observed on the computer monitor (without additional monitor equipment) in a continuous or step way (stop-frame). It can be introduced directly (through the TLP-640 card) to the operational memory at the resolution of 640 points x 255 lines.

A new version of the system comprises of three main procedures:

1. Introduction of pictures from the camera, their correction and scaling;
2. Formation of the data basis (analysis, registration and search for data);
3. Graphical and statistical processing of the data registered.

The TRANS_DIG program package, version 3.0, has been written in the PASCAL and assembler languages. It is user friendly due to a readable pull-down menu and a PC-mouse implementation.

2.4. Analysis of Strong Refraction Effects in Optical Diagnostics of Dense Plasmas (CPBP 01.10.03.1.1.)

by W.Pawłowicz

Interferometry and Schlieren photography are the well known experimental methods used to measure a refraction index distribution inside plasma objects transparent for a probing laser beam. In order to penetrate a high density plasma (above $10^{21}\mathrm{cm}^{-3}$) one must use a short-wave length radiation below the NUV range. Such radiation sources are rather unique and difficult to be applied. To increase a measured density range, one can also use a larger aperture and detect rays refracted at larger angles. It leads to some new experimental and interpretation problems, because assumption of a negligible refraction becomes invalid.

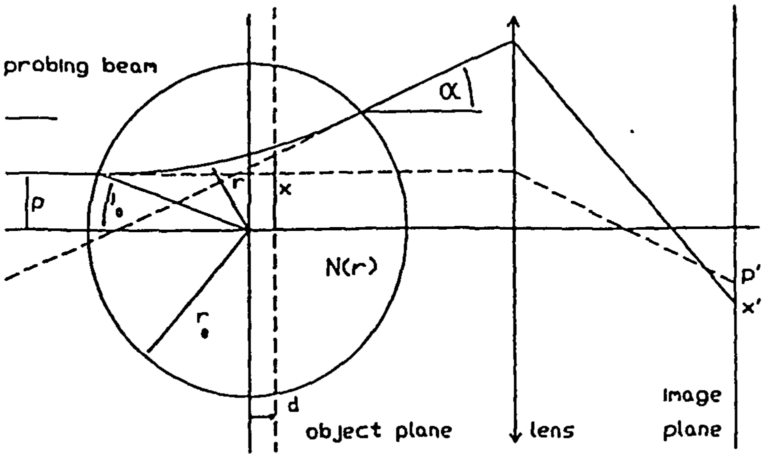

Fig.2. Probing rays penetrating an inhomogeneous plasma of cylindrical symmetry.

Effects of a strong refraction and the ray crossing have been analyzed for plasma objects of cylindrical symmetry, as shown in Fig.1. Taking into account geometrical relationship it has been possible to derive [6] a general formula for the optical path difference:

$$\Delta S(p) = S(p) - 2\sqrt{r_o^2 - p^2} + p\cdot \mathrm{tg}\,\alpha + d\cdot(1/\cos\alpha - 1)$$

where: $\sin\alpha(x) = d(\Delta S)/dx$

It has been shown that for a strong refraction the additional terms cannot be neglected. Simultaneously, a role of the positioning of the object plane in relation to the symmetry axis, which is of little importance when a small refraction occurs, has been found very important for strongly refracting objects. In order to estimate the effects in question some numerical calculations have been performed [6] for density profiles described by exponent functions.

2.5. Numerical Simulation of Operation of Current-Pulse Generators

(CPBP 01.10.01.04)

by B.Bartolik and K.Kocięcka

The study has been a continuation of investigations performed previously, those involved experimental and computational studies. It was anticipated that on the basis of new numerical codes [7] verified by appropriate measurements in the existing HV generators, it would be possible to simulate the operation of pulse current generators with a complicated structure, which are used for powering plasma experiments.

It has been found long ago, that the resistance of spark-gaps can be described by the Rompe-Weizel formula. Additionally, it has been assumed that for a spark-gap of the field-distortion type a breakdown in each gap develops according to the Heilbronner formula found for a single spark-gap. It has been investigated whether for a breakdown initiated artificially the Heilbronner formula can also be used in numerical calculations. The studies have been carried out at different electrical loads of a generator, as a function of a steering coefficient. It has been found that the value of the Heilbronner's constant, Hc1, as measured for the first gap, does not depend considerably on parameters of P circuit, as shown in Fig.3. The value of Hc2, for the second gap is a function of the steering coefficient and it decreases with an increase of in the Ks value. Therefore, in preliminary calculations one can apply an average value of the Hc, while in exact computations the Hc(Ks) function should rather be used.

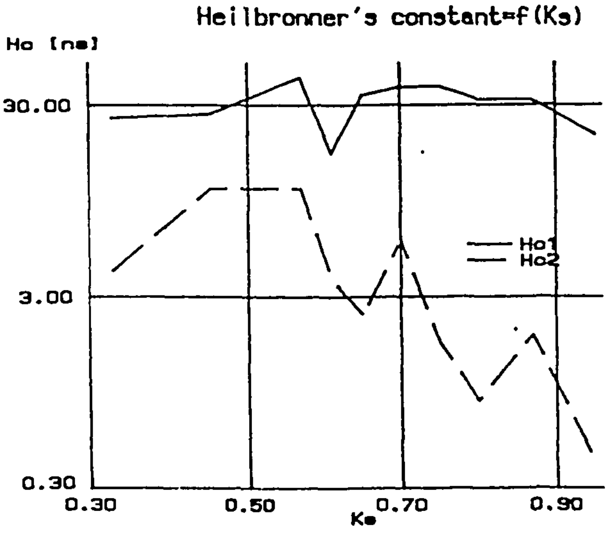

Fig.3. Results of measurements of Heilbronner's constants: Hc1 - for the first gap from the condenser side, Hc2 - for the second gap, versus the steering coefficient Ks.

2.6. Study of Atom in External Magnetic and Electric Fields

(CPBP 01.10.10.05)

by M.Gryziński and M.Kowalski

In a quantum theory, the atom is assumed to be a spherically symmetric structure and, therefore, discussion of the hydrogen atom rotation does not make any sense. In a classical theory the atom is a well defined system of point-like particles and electrons creating well specified spatial configuration, which as a whole can rotate around the nucleus. Some time ago[*] it was demonstrated that the classical atom placed in an external magnetic field adjusts its orientation to minimize energy of the system, as shown in Fig.4. It follows from above that collision cross sections are anisotropic and this anisotropy should be taken into account in calculations performed for magnetized plasmas.

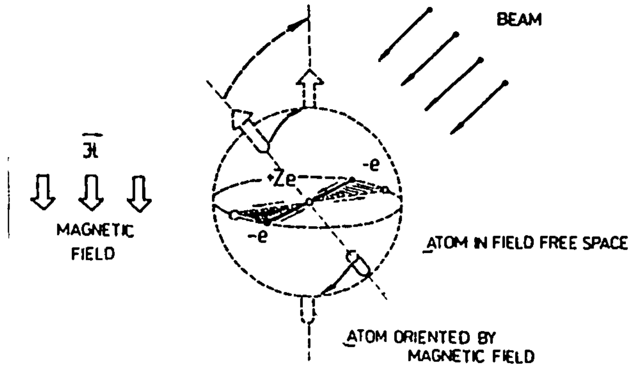

Fig.4. Reorientation of the He-atom in the external magnetic field.

During recent investigations of p+H collisions we have discovered existence of the H atoms alignment in an electric field of a projectile proton, as shown in Fig.5. The proton scattered may capture an atomic electron or not. Capture probability, as a function of the proton energy, can be calculated correctly under assumption of an alignment of the zero angular momentum free-fall orbit of the atomic electron, with respect to the proton electric field.

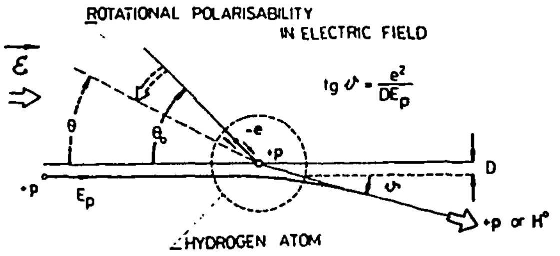

Fig.5. Geometry of a collision between a proton and the hydrogen atom.

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[*] M.Gryziński: J.Magnetism Mat. 71(1987)53.

2.7. Analysis of Electron Mechanism of Coulomb Barrier Tunneling

(CPBP 01.10.10.05)

by M.Gryziński

The existing theory of the Coulomb tunneling has just been questioned. A hypothesis has been raised that negatively charged electrons, those accompany any nuclear collision, make possible the Coulomb barrier tunneling. In such a way, solving approximately a three body collision problem, the Gamov relation has recently been derived.

Adopting a quasi-molecular mechanism of the Coulomb barier tunneling a new model of the cold fusion in a Pd crystal-lattice has been proposed. It has been assumed that hydrogen atoms inside the Pd-lattice exist in the form of linear H_2^+quasi molecules, as shown in Fig.6. Such H_2^+ quasi molecules during $\alpha \rightarrow \beta$ phase transitions can lose stability and collapse to a nuclear size.

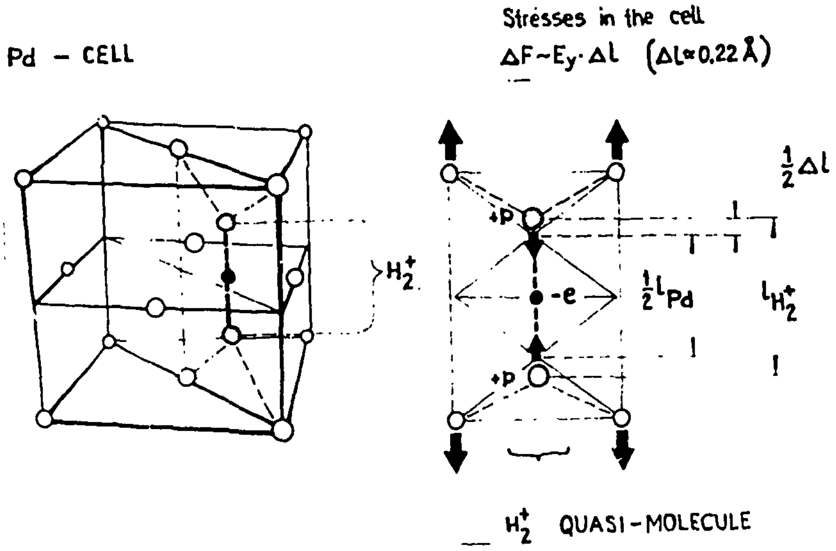

Fig.6. Localization of the H_2^+ *quasi-molecule inside the* Pd*-lattice.*

From the model developed it follows that a fusion cross-section for a low energy range, may depend strongly upon density of matter and its temperature. Since all the existing calculations of the fusion energy production in plasma systems were carried out under the assumption that the fusion cross-section is independent of the state of matter, their results can be burdened with large errors, and it might involve big consequences for further fusion research.

3. EXPERIMENT

3.1. Study of Temporal Characteristics of X-Ray and Ion-Beam Emission from IBIS Facility (CPBP 01.10.03.2.1)

by E.Składnik-Sadowska, J.Baranowski, and Z.Puchalski

In order to determine emission characteristics of the IBIS facility [1] use was made of different pinhole cameras and energy analyzers adopted to measurements of X-rays and ions. Detailed studies of ion beams emitted along the z-axis have been performed [8] by means of the IPCA-TR ion pinhole camera with a variable magnification, as shown in Fig.7, and by means of the IPCB-TR multi-pinhole camera. Simultaneously with ion studies, there have also been performed X-ray observations with XPCA-TR camera equipped with an additional measuring head with miniature scintillation detectors.

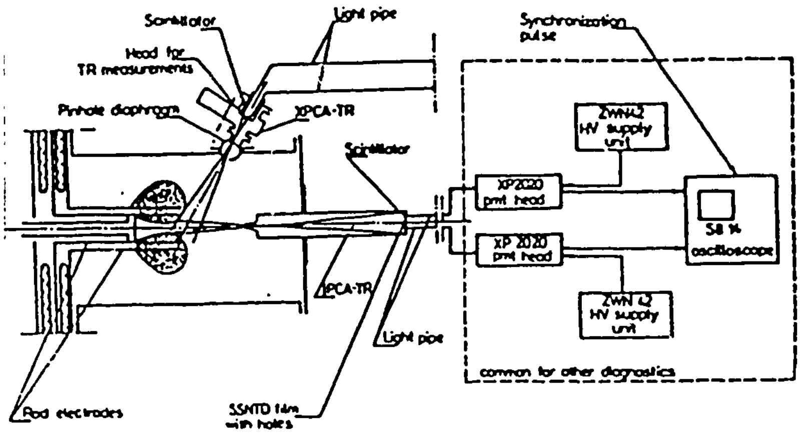

Fig.7. Scheme of the IBIS facility with some diagnostics equipment.

Time-resolved X-ray and ion signals have been transmitted through plastic optic cables to a Faraday cage, where measuring heads with the XP2020 photomultipliers were located. The measurements, as carried out for different operational modes at the IBIS facility, have shown that the ion emission depends strongly upon initial gas conditions within the interelectrode region. Fig.8 presents an example of the correlation of ion pulses (with time shifts corresponding to different energies), and X-ray signals, as observed some 80 cm from the IBIS electrodes. It has been observed that the X-ray pulses are emitted mostly from the plasma stream center [8].

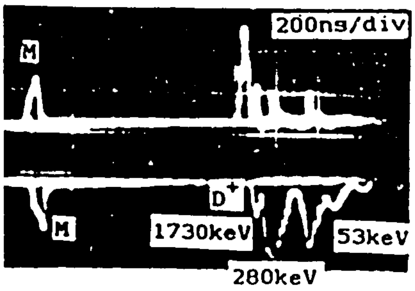

Fig.8. Time-resolved X-ray and ion signals

3.2. Investigation of Reaction Proton Emission from IBIS Plasma Facility (CPBR 5.8 - 2.19.2b)

by J.Hoszowska, J.Baranowski, Z.Puchalski,
and E.Składnik-Sadowska

Within a framework of studies on fusion reaction products particular attention has been paid to fast (about 3.0 MeV) protons generated in one of branches of the d-d reactions. The proton measurements have been carried out by means of an ion pinhole camera equipped with a set of nuclear track detectors of the CR-39 type. Those detectors have been covered by an absorbing Al-foil of 100 μm in thickness, and they have been placed at different angles in relation to the z-axis of the IBIS facility [1], as shown in Fig.9.

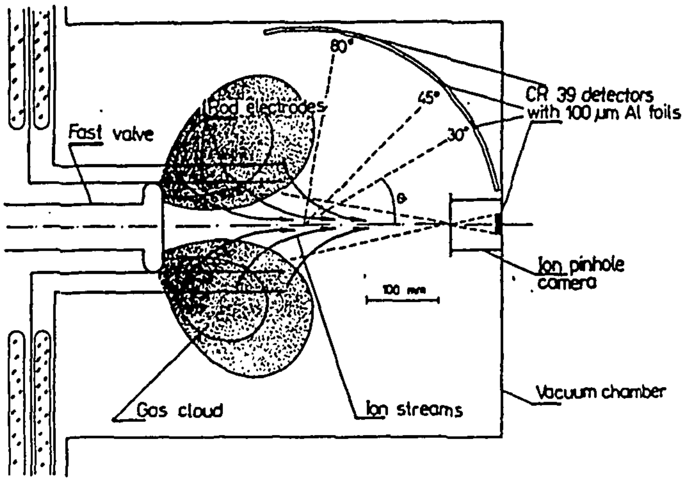

Fig. 9. Localization of the CR-39 track detectors within the IBIS facility.

On the basis of detailed measurements performed for different modes of the IBIS operation it has been observed [9] that there exists a close relation between mechanisms of deuteron acceleration, yield of the d-d reactions, and an energy distribution of reaction protons emitted within energy range 2.6 MeV ≤ E_p ≤ 3.6 MeV, as shown in Fig.10.

Analyzing angular distributions of the reaction protons, it has been found that the emission is strongly anizotropic, and the main sources of these protons appear at the z-axis of the system [9].

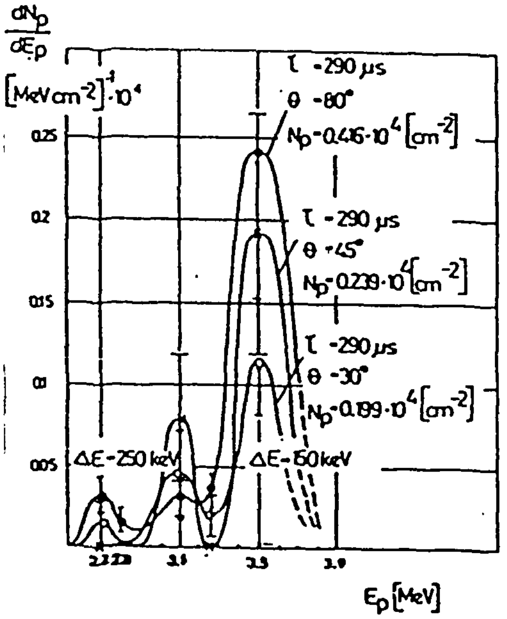

Fig.10. Energy spectra of fusion protons emitted at different angles.

3.3. Optimization of High-Current Plasma Discharges in MAJA-PF Facility (CPBP 01.10.03.2.3)

by L.Jakubowski, M.Sadowski, and J.Żebrowski

Within a scope of Plasma-Focus (PF) studies, carried out partially within a framework of on international cooperation [10], new optimization tests of the MAJA PF-facility [1] have been performed as the continuation of the previous studies [11-12]. For the gas puffing use has been made of an electromagnetic valve placed inside the inner electrode and directed towards the electrode end. In order to optimize high-current PF discharges, several series of experiments have been performed [13]. Integral measurements of X-rays have been carried out with different pinhole cameras, and time-resolved observations have been realized by means of the XET-type analyzers. Particular attention has been paid to correlations of X-ray and neutron pulses. An evaluation of the electron temperature has been made for different modes of the operation of the MAJA-PF facility, and a dependence of an integral neutron yield on the experimental conditions has been investigated, as shown in Fig.11. On the basis of the studies performed [13], it has been found that the neutron yield depends very strongly upon amount of working gas injected before the PF discharge. This dependence is similar to that observed under static initial pressure, but the maximum yield appears at a different pressure value, depending on the energetic level.

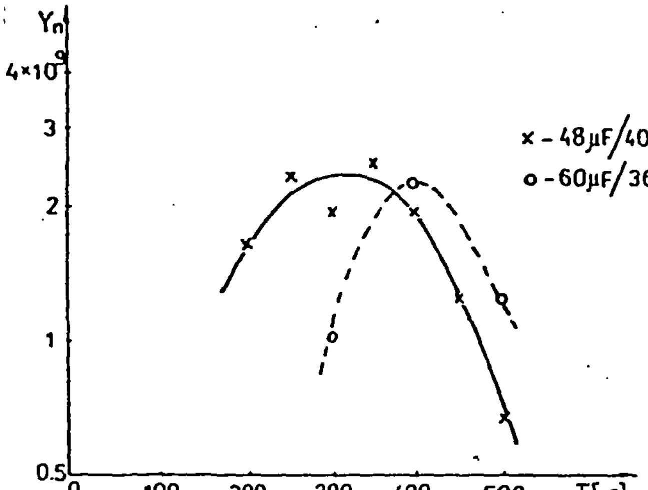

Fig.11. Neutron yield as a function of a time delay in the gas valve operation under different experimental conditions.

3.4. Preliminary Studies of Electron Beams Emitted from PF Facilities (CPBR 5.8 - 2.19.2b)

by L.Jakubowski, M.Sadowski, and J.Żebrowski

Measurements of relativistic electron beams emitted from the PF facilities, can supply many important information about the dynamics of the PF-type discharges. To make possible such studies various methods have been applied, and a special diagnostic equipment for space- and time-resolved measurements of e-beams has been developed [14]. Experimental studies of e-beams have been performed at different PF facilities in Świerk [14], and at the large POSEIDON facility in Stuttgart [15].

A spatial distribution of e-beams, which are emitted along the z-axis in the upstream direction and escape through a hole in the inner electrode (anode) of the PF system, has been investigated by means of the NE102A-plastic foils shielded with mosaic filters [14-15]. The Cherenkov radiation has been registered with a photo-film, and corresponding densitometric measurements have shown that there are emitted bunches of e-beams of energy up to about 600 keV. Time-resolved measurements have been performed with the XET analyzers adopted for the registration of the Cherenkov radiation [14-15]. The results obtained have shown that there appear several electron pulses with the HWHM equal to about 30 ns. To measure an energy spectrum of e-beams from the PF-360 facility, use has made of an external magnetic analyzer equipped with photo-films protected with appropriate metal filters [14]. The results obtained have demonstrated that the maximum e-beam intensity appears within an energy range from 180 keV to 600 keV, as shown in Fig.12.

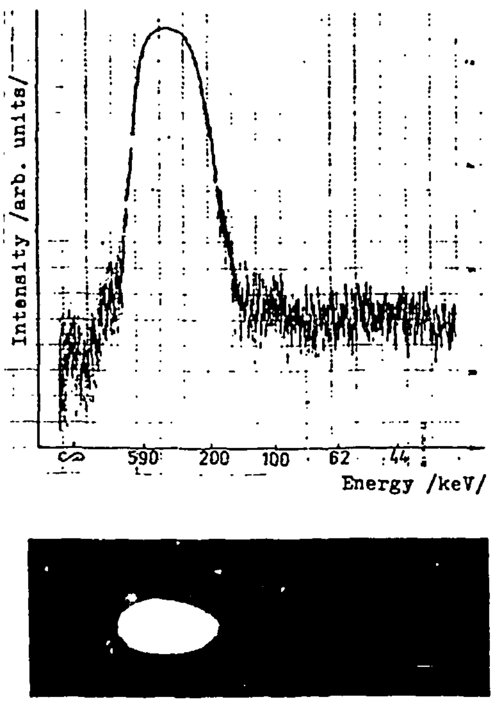

Fig.12. Energy spectrum of e-beams emitted from the PF-360 facility, as obtained with magnetic analyzer.

3.5. Investigation of PF-360 Device under Dynamic Gas Conditions

(CPBP 01.10.04.02)

by A.Jerzykewicz, K.Kocięcka, and W.Nawrot

Recent investigations have been the continuation of the studies initiated before [1], in order to make possible mastering the neutron yield saturation effect by means of the gas-puffing into an interelectrode region. For a new series of experiments [16] use has been made of a special high-pressure gas valve powered from a separate condenser bank with a regulated charging voltage. An operational pressure has been varied by change of a time delay of the main discharge.

Detailed measurements of voltage- and current-waveforms, neutron yields, and time-resolved neutron signals, have been performed. For a comparison experimental studies have been carried out under static and dynamic gas conditions. Particular attention has been paid to the role of a background deuterium pressure, an initial pressure of deuterium supplied to the valve, a charging voltage, and a time delay in the operation of the main current generator, as shown in Fig.13. The results obtained have shown that for PF discharges performed at the appropriate background pressure, and with the use of the valve, the total neutron yield is similar to that obtained under static gas conditions. At a very low background pressure, the shots performed under dynamic gas conditions reveal a neutron yield one order of magnitude lower than that observed under the static gas conditions, and Y_n depends very strongly on parameters of the valve operation. However, under dynamic gas conditions there can also be formed a distinct current sheath.

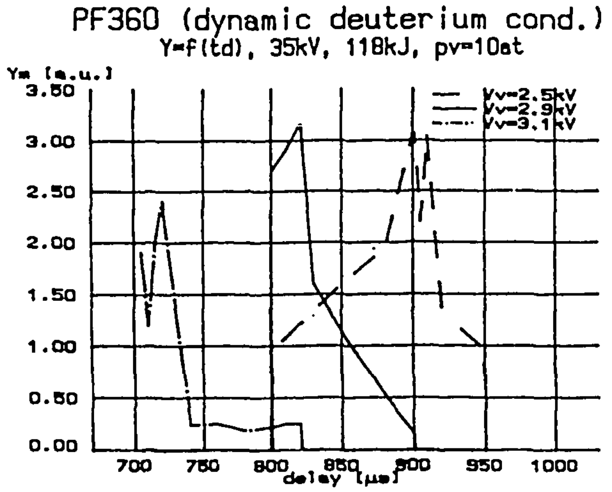

Fig.13. Neutron yield as a function of a time delay of the main plasma discharge in relation to the gas valve operation.

3.6. Development of Time-Resolved Diagnostics for Plasma-Focus Experiments (Contract MPHH-84/88)

by M.Sadowski, J.Baranowski, K.Czaus, L.Jakubowski, and E.Składnik-Sadowska

In order to make possible time-resolved studies of X-rays and ions emitted from high temperature plasmas, and in particular from PF-type discharges, a new modernized diagnostic equipment has been designed, manufactured, and tested [17].

X-ray pinhole cameras with rotated films (XPC-00A) and other ones with variable magnifications (XPC-00B) have been equipped with additional measuring sets containing miniature scintillation detectors and plastic optic cables, which can be coupled with separate photomultipliers and oscilloscopes [18-19]. The time-resolving equipment for the X-ray pinhole camera with the rotated film (XPC-ATR) makes possible measurements in two selected points of an X-ray image [20], while such an equipment for the camera with a variable magnification (XPC-BTR) enables observations in several points to be performed [21].

To make possible more accurate energetic and temporary analysis of X-rays, some new versions of the XET analyzers have been developed. The XET-2CH instrument constitutes a two-channel analyzer equipped with separate filter-scintillator sets and one addition X-ray filter fixed to a rotatable arm [22]. The XET-6CH instrument constitutes a modified X-ray analyzer equipped with a multi-pinhole diaphragm and six separate absorber-scintillator sets [23].

Ion pinhole cameras (IPC-00A) and ion multi-pinhole cameras (IPC-00B) have also been equipped with time-resolving systems, which contain miniature scintillators (with additional light-tight coatings) and separate optic cables [24-25].

In order to enable precise mass- and energy-analysis during time-resolved studies of ions escaping from a plasma, the Thomson-type mass-spectrometer (TMS-000) has also been equipped with an additional end plate with several miniature scintillators, which can be placed in chosen points of the parabola tracks and observed through separate light-pipes connected with fast photomultipliers [26].

3.7. Study of Magnetic Control of Plasma Discharges in SOWA-400 Experiment (CPBP 01.10.01)

by M.Gryziński, W.Komar, and J.Stanisławski

The main problem of ion beam fusion studies in the SOWA-400 experiment [27] has been acceleration of ions in magnetically self-controlled low pressure plasma discharges. A modification of gas conditions between cylindrical electrodes has been one of the ways to control plasma discharges. The application of an external magnetic field to the discharge has been the other method. The main aim of the studies performed in 1990 was to investigate possibility of a magnetic control of the mirror-symmetry discharges within the SOWA-400 facility.

In the case of cylindrical electrodes connected at both ends with two identical energy-storage units, a magnetic field at the central symmetry plane of the system is equal zero. This is the only plane where an electron current in a collision plasma discharge can easily flow to the anode. In order to control this current two additional ring-straped magnetic coils have been placed the mid-plane of the device, as shown in Fig.14. The coils of about 30 cm in diameter have been supplied from a separate 15-kV condenser bank, and the magnetic field up to 12 kGs has been produced between the electrodes. Changing the direction of a current flow in the two coils applied, one could also change the distribution of the produced magnetic field. Some preliminary results of research on influence of the magnetic field upon the discharge have been obtained [28].

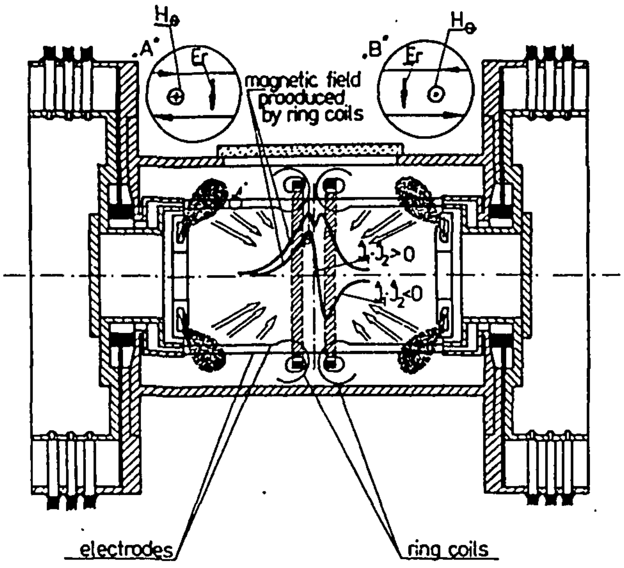

Fig.14. Scheme of the SOWA-400 facility with two additional magnetic coils.

4. TECHNOLOGY

4.1. Final Design and Tests of Multichannel Optoelectronic Transmission·System for TOKAMAK Experiments (CPBP 01.10.01.1.4)

by M.Bielik

In 1990, technological activities connected with the elaboration of the multi-channel opto-electronic transmission system [1], have been continued. A new emitters crate has been designed and assembled [29] for 20 transmission channels equipped with the DIDO-type amplifiers and opto-electronic transmitters, as shown in Fig.15. A new supply system for the emitters crate has also been constructed. It makes possible to use the crate at potential below 20 kV. The ON-OFF switching system enables a remote control by means of the Fiber-Optic separation from the receivers crate, which is to be placed inside a control room of the Data Acquisition Station at the T-15 tokamak experimental facility. Signalling of the appearance of supply voltage in the emitters crate, is also possible through the FO separation.

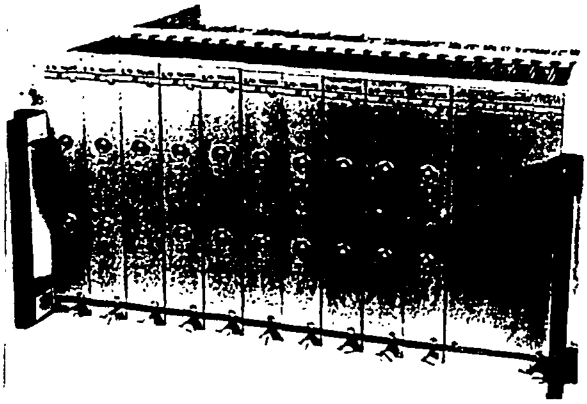

Fig.15. General view of the emitters crate containing 20 amplifiers with opto-electronic transmitters and DC-1 converter

The requirement of electric isolation (up to 20 kV) for the whole emitters crate is fulfiled by a special transformer. In order to assure inter-channel isolation (up to 1 kV) and to miniaturize transformers for separate channels, the conversion of a supply frequency (from 50 Hz into 10 kHz) has been applied. A frequency converter of the DC-1 type has been located within the emitters crate, and the ON-OFF switching and signalizing systems have been connected through the isolation transformer. Final laboratory tests and measurements of transmission parameters have been performed, in particular for a very low frequency range (down to 0.05 Hz). During those measurements carried out with square- and triangle-signals, no temperature effects neither additional drifts have been observed [29].

4.2. Modification of Diagnostic Equipment for Plasma Experiments

(CPBP 01.10.03 and CPBR 5.8)

by M.Sadowski, J.Baranowski, K.Czaus, L.Jakubowski, Z.Puchalski E.Składnik-Sadowska (P-V) and M.Kowalski (ZDAJ)

Within a framework of the modernization of diagnostic tools used for different plasma experiments at SINS, besides the development of time-resolving equipment for X-ray and ion pinhole cameras and analyzers [17-26], particular attention has been paid to analysis of investigated waveforms. For this purpose use has been made of a new Digitizing Camera System (DCS) consisting of a CCD camera coupled with an IBM-PC equipped with a video Frame Store Board (FSB) of the Tektronix-type. The system applied makes possible fast analysis of registered traces and their storage [30]. An appropriate soft-ware helps in data processing and supplies printed records with a required magnification. It enables the correction of parameters of a plasma discharge to be performed during a series of experiments. It makes the optimization of plasma facilities more easy.

The DCS has been tested for registration of soft X-ray signals and neutron pulses at the IBIS and MAJA-PF facilities [30]. The method has proved to be more accurate than the conventional one, as shown in Fig.16.

Other efforts have been devoted to the modification of a system for counting of pulses from the Geiger-Muller counter [31], and to the elimination of nuclear radiation influence on the opto-electronic transmission lines [32].

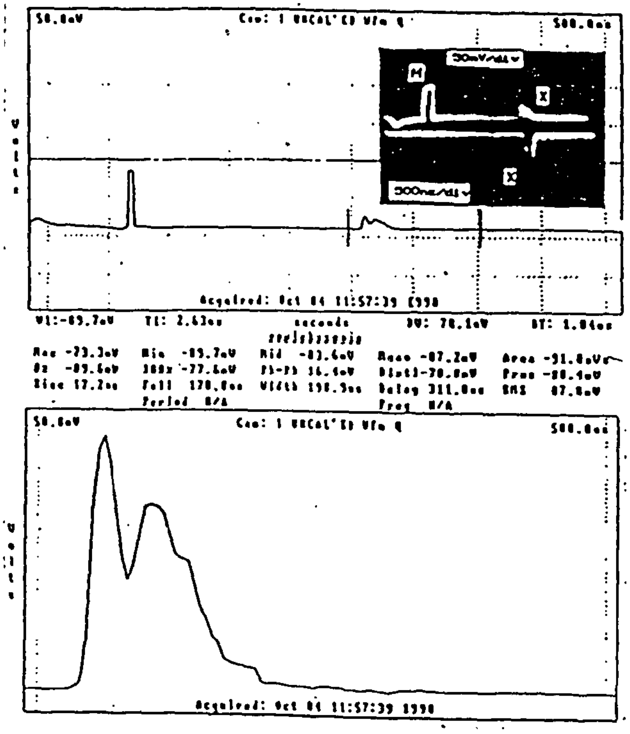

Fig.16. Comparison of X-ray signals registered with a fast oscilloscope and with the DCS.

4.3. Design and Construction of New Plasma-Focus Facilities and Subunits (CPBP and Contracts)

by M.Bielik, Sz.Brandt, A.Jerzykewicz, K.Kocięcka, L.Kociński, R.Mirowski, W.Nawrot, W.Polak, R.Rybicki, J.Witkowski, W.Wyszyński (P-V), and S.Śledziński (IFPiLM)

Plasma-Focus PF-1000 Facility (CPBP 01.10.04.01.4)

In 1990, the final assembling of condenser sections and auxiliary systems was finished. The PF-1000 collector plate with one of electrode versions has been connected with the main experimental chamber and a pumping system. The main charging unit and high-pressure gas blowing installations have been assembled and tested. Laboratory activities have been concentrated on the completion of all the basic systems and installation in order to enable technical tests of the generator sections together with the short-circuit collector system [33].

PF Capacitor Bank Unit (Contract MPH-84/88)

An auxiliary equipment for the PF-360E facility [34, 36] have been completed and delivered according to the contract.
This equipment has been consisted of:
- a control desk [37],
- a vacuum pumping station [38],
- a charging unit of the C50/50 type [39],
- an automatic system for deuterium supply [40].

The PF-360E facility has been equipped with a complex pneumatic system [41-42], which can supply cleaned and pressurized air for high-voltage spark-gaps.

Other PF-Laboratory Equipment (Contract MPH-84/88)

For future neutron measurements during plasma experiments, new silver activation counters [43] and scintillation detectors [44], have been manufactured. These counters and detectors have been adopted to operate together with a modern computer system.

In order to enable accurate voltage measurements to be performed, new 100-kV [45] dividers have been designed and manufactured.

The PF-360E condenser bank has been equipped with a separate master-trigger generator [46]. In order to make possible testing of the PF-360E current pulse generator and other high-voltage laboratory activities, there has also been delivered an auxiliary high-voltage laboratory equipment [47].

Data Acquisition System (CPBR 5.8-2.19.2)

In 1990, a new prototype of the data acquisition system with the transmission band ranging up to 250 MHz has been elaborated [48]. This system has been equipped with the Tektronix card and a CCD camera, which can cooperate with a fast oscilloscope of the SI-97 type.

Simultaneously, there has been designed another system for transmission of slow-variable signals by means of a voltage/frequency/optical-signal converter, an optic cable, and an optical-signal/frequency/voltage decoder /49/.

Additionally, there has been designed and manufactured following auxiliary equipment:

- a separate card for registration of signals from neutron counters, and for measurements of time intervals,
- a generator of marking signals used for the correlation measurements of fast-variable waveforms.

Prototypes of the equipment mentioned above have been tested, and the results obtained have been presented at the topical international conference [49].

4.4. Design and Construction of SOWA-1000 Facility

(CPBP 01.10.02-03)

by M.Gryziński, K.Czaus, A.Horodeński, and J.Stanisławski

According to the project on design and construction of a high-current pulse generator for the SOWA-1000 facility, a new high-voltage supply system for a condenser bank has been built [50]. This system consists of two identical three-phase charging power units of following parameters:

charging voltage	10 - 50 kV,
maximum charging current	200 A,
accuracy of the charging voltage control	<0.5%.

In order to enable the localization of possible damages in the SOWA-1000 condenser section, a special electronic system has been designed and constructed [51].

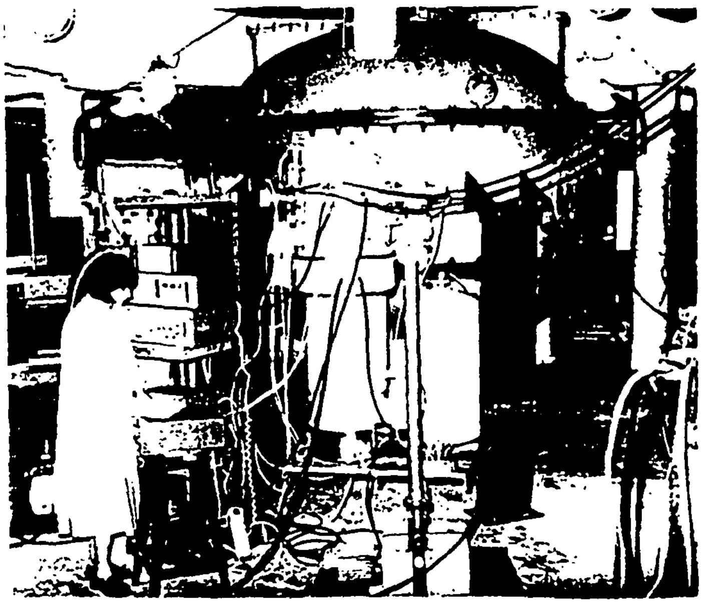

Fig.17. The manufactured segment of the main vacuum chamber for the SOWA-1000 experiment. Volume of the segment is about 7 m^3 and its inner surface area is about 18 m^3.

Within framework of the construction of the vacuum system for the Sowa-1000 facility. an important part of the main vacuum chamber has been manufactured, as shown in Fig.17. The segment was assembled and tested by means of two pumping systems consisting of the SP-6000 diffusion pumps and the BL-90 rotary pumps. A background pressure of $3\mathrm{x}10^{6}$ torrs has been achieved, and the leakage has been limited to the acceptable value of the order of 5×10^{-3} torr·l/sec.

In order to make possible the formation of a high density gas target inside the experimental chamber, a new fast gas valve has been designed, and its prototype has been constructed.

4.5. Application of Pulsed Ion-Plasma Streams for Modification of Solids (CPBR 5.8 - 2.18)

by J.Langner, J.Appelt, A.Horodeński, W.Ziemski (P-V)
J.Piekoszewski, C.Pochrybniak, J.Białoskórski, J.Zaręba (ZDAJ)
L.Waliś, A.Ciurapiński (IChTJ), and A.Turos (P-II)

During recent years, it was proved that complete photovoltaic structures of the p^+-n-n^+ and n^+-p-p^+ type can be effectively produced in silicon wafers with plasma streams containing BF_3^- and PF_5^- ions. In 1990, photovoltaic cells of the average conversion efficiency of about 12% (the maximum 14.5%) were obtained, and a photovoltaic battery of 3-W power was produced.

Within the field of studies on the modification of solids, hardening and doping tests of steel samples were carried on. An increase in microhardness of a non-alloyed steel, resulting from an irradiation with hydrogen or nitrogen plasma streams, was obtained. For alloys of the NCLV- and WCL-types, some microhardness decrease was observed (ranging from 15% to 50%), which could be explained by a relatively low intensity of the applied plasma streams. Mossbauer spectra of the 1H18N9T- and N9-steel wafers, before and after the irradiation of the those with hydrogen and nitrogen plasma streams, have also been obtained [53]. In the case of the 1H18N9T sample a distinct increase of the central line has been observed, which indicated growth of the austenitic phase, as shown in Fig.18.

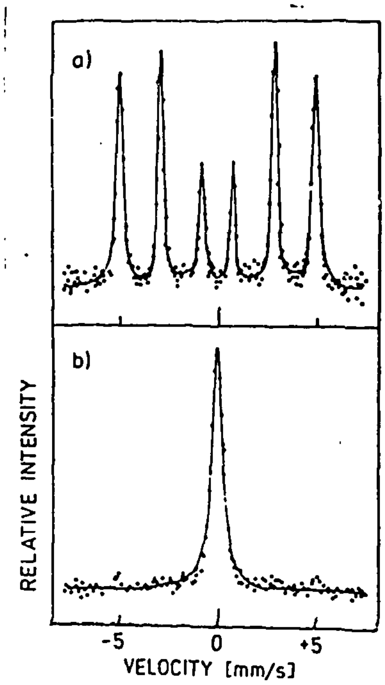

Fig.18. Conversion electron Mossbauer spectra (CEMS) of virgin N9 sample (a) and of irradiated one (b).

The "hot-coating" method has also been used for the production of Cu/Mo and W/N9-steel layers. Some tests have also been performed with the glazing of solid and plasma-sprayed ceramics. It has been found that roughness of the alumina and zirconium ceramics can be considerably decreased as a result of plasma irradiation, i.e., R_o and R_z can be reduced by 1.6 and 2.3 respectively.

4.6. Investigation of Plasma-Wall Interactions by Means of IONOTRON-Type-Devices (CPBR 5.8 - 2.19)

by J.Langner, W.Ziemski (P-V), and T.Wolski (IEA)

Studies of plasma-wall interactions have been carried out at SINS since 1989. The first goal was to verify applicability of IONOTRON-type devices, e.g. the IBIS facility [1], for the simulation of phenomena occurring at the first wall of a fusion reactor during rise of disruptive instabilities. It has been found experimentally that steel and ceramic wafers, which were exposed to plasma streams of energy density above several dozen joules/cm^2, exhibit surface deformations similar to those observed at the first wall of the tokamak-type reactor.

In 1990, particular attention was paid to development of methods of surface temperature measurements during interactions of strong pulse plasma streams [54-55]. Experimental studies were concentrated on the irradiation of tungsten wafers, which are often used to cover tokamak divertor plates. The tungsten layers were sprayed upon copper, lead, and austenic steel samples by means of the plasma spraying technique. Quality of the tungsten layers was tested with crystallographic methods. The wafers were exposed to plasma beams of energy density exceeding 10J/cm^2. A loss of mass, resulting from evaporation sputtering, has been measured, to be 0.05 to 0.25 mg/cm^2.

The irradiated wafers have been investigated with scanning electrode microscope (SEM) technique, as shown in Fig.19. It has been found that the evaporation efficiency depends considerably on quality and granulation of the W-powder applied.

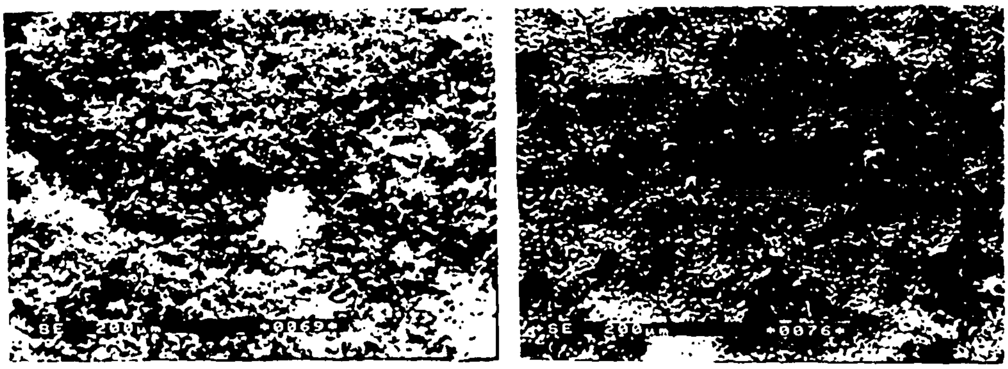

Fig.19. SEM pictures of a surface of the tungsten layer upon the Cu-base, taken before (a) and after (b) irradiation.

4.7. Design and Tests of Laboratory Facility for Production of Miniature Cryogenic Pellets (CPBP 01.10.03.2.3)

by M.Sadowski, A.Szydłowski, L.Jakubowski, and E.Ćwiek

Miniature cryogenic pellets have recently become very attractive for nuclear and thermonuclear experiments. The hydrogen and deuterium cryogenic pellets have been used e.g. in tokamak and laser fusion experiments. In order to apply such pellets in high-current plasma concentrators at SINS, a liquid H_2 droplets generator has been designed and assembled [56].

The main part of this facility constitutes a liquid helium-cooled cryostat, as shown in Fig.20. The liquid helium coolant is taken from a Dewar vessel to the cryostat heat exchange system through a special vacuum siphon. The helium flow rate is measured with a rotameter and regulated by means of a metering valve. In order to control temperature values, us is made of a 850-ohm Bradley-type carbon resistor, which is placed at the cryostat heat exchanger. Temperature is measured by passing a 1-μA current through the resistor and measuring a voltage drop. To control a temperature value an electrical heater is applied, which has been wound around the heat exchanger and connected to a power supply through a special electronic unit.It enables the temperature to be stabilized with accuracy of ±0.1 K. The whole cryostat is is placed inside a vacuum chamber pumped out to a background pressure below 10^{-3}Tr. Experiments on the production of liquid hydrogen and deuterium droplets of a controlled size, have just been started.

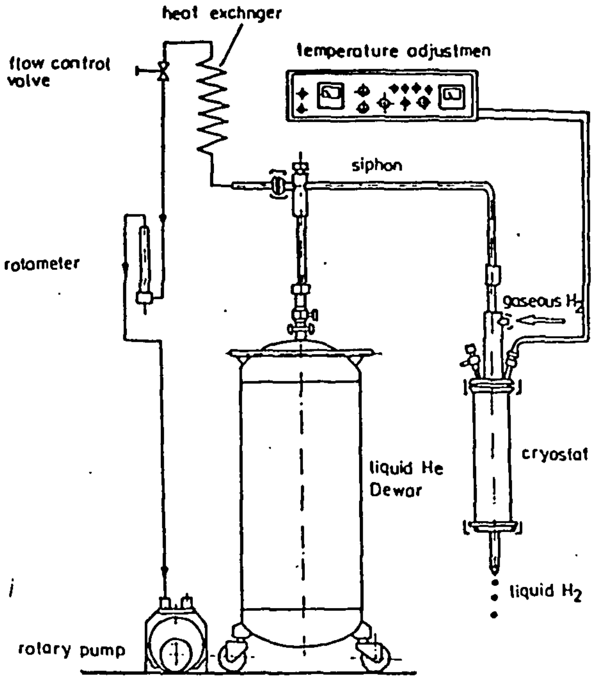

Fig.20. Scheme of laboratory facility for production of cryogenic pellets.

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2. One-Dimensional Modeling of Tokamak Edge Plasma Transport in Grad Approximation, by M.Rabiński; Contrib. Plasma Phys. 30(1990) pp. 121-126.

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6. LECTURES PRESENTED AT EXTERNAL SEMINARS AND SYMPOSIA (UNPUBLISHED)

1. M.Sadowski: Energy from Nuclear Fusion Reactions, Studies, Achievements and Prospects (in Polish); an invited lecture presented at the Seminar on Energetic Problems, organized by the Warsaw Scientific Society, Warsaw, March 20, 1990.

2. M.Rabiński: Investigation of a Model of Nonlinear Transport for Tokamak Edge Plasma (in Russian); a lecture presented at the Seminar on Theory of Plasma Processes in Tokamak Reactor, organized by the Kaliski Institute of Plasma Physics and Laser Microfusion, Warsaw, April 3, 1990.

3. Z.Jankowicz: Model of Scrape-Off Plasma with Account to Plasma Currents in Real Toroidal Geometry (in Russian); a lecture presented at the Seminar on Theory of Plasma Processes in Tokamak Reactor, organized by the Kaliski Institute of Plasma Physics and Laser Microfusion, Warsaw, April 3, 1990.

4. W.Pawłowicz: Role of Strong Refraction Effects in Optical Diagnostics of Dense Plasmas, a lecture presented at the 5th National Topical Meeting on High-Temperature Plasma Diagnostics, Mińsk, June 18-22, 1990.

5. J.Żebrowski, M.Sadowski, and A.Szydłowski: Influence of Nuclear Radiation on Opto-Electronic Systems Used for Diagnostic Signals Transmission; an invited lecture presented at the 5th National Topical Meeting on High-Temperature Plasma Diagnostics, Mińsk, June 18-22, 1990.

6. M.Gryziński, M.Kowalski, and M.Wlazło: Rotational Polarisability of Classical Atom in p+H Collisions, a lecture presented at the Conference on Physics of Highly-Charged Ions, Giessen, September 10-14, 1990.

7. Z.Jankowicz: Non-Ambipolar Classical Scrape-Off Layer Model for a Real Toroidal Geometry; a lecture presented at the IAEA Technical Committee Meeting on Research Using Small Tokamaks, Arlington, September 27-28, 1990.

8. M.Gryziński: Molecular Mechanism of Cold Nuclear Fusion in Solid State Matter,an invited lecture presented at the International Conference on Anomalous Nuclear Effects in Deuterium/Solid-State System, organized by the Electric Power Research Institute and the Brigham Young University, Provo, October 18-25, 1990.

9. M.Gryziński: Perspectives of Controlled Nuclear Fusion and Molecular Mechanism of Coulomb Barrier Tunneling; Cold Fusion in Hydrogen and Palladium Lattice; Is Theoretical Physics Pursuing a Correct Course?; three lectures at Seminars organized by the Electric Power Research Institute, Palo Alto, October 26-31, 1990.

10. M.Gryziński: Selected Theoretical Problems of Atomic Physics; Ion Optic Fusion Studies at SINS in Świerk; two lectures presented at Seminars organized by the Southern California University, Los Angeles, November 1-10, 1990.

11. M.Gryziński: Low Energy Atomic Collisions, an invited lecture at the Seminar organized by the Harvard University, Boston, November 10-17, 1990.

12. M.Gryziński: Physics of Atomic Collisions, an invited lecture at the Seminar organized by the National Bureau of Standards and Technology, Washington, November 18-25, 1990.

13. M.Sadowski: Status of Plasma-Focus Studies in Poland, an invited lecture at the Workshop on Plasma and Pulsed Power, organized by the Lebedev Institute and the Moscow Physical Society, Zvenigorod, December 10-16, 1990.

14. M.Sadowski: Generation of Cryotargets for Dense Plasma Experiments, an invited lecture at the Seminar organized by the Dept. of Radiation Sciences at the Uppsala University, Uppsala, December 20, 1990.

15. J.Kuciński: Calibration of Neutron Yield Activation Measurements at ASDEX-Tokamak; Parameter Studies of Neutron Production at ASDEX for L&H Modes, two lectures presented at the Plasma Seminar organized by the Heidelberg Uni., Heidelberg, December 18, 1990.

7. LIST OF VISITORS.

1. Prof. G.L. Saksaganskij
2. Dr. V.I. Litunovskij
   both from the Scientific-Research Institute of Electro-Physical Equipment in Leningrad, S.U.,
   visited the Dept. P-V on January 15-22, 1990.

3. Prof. I.P. Panchenko
   from the Kharkov Civil Engineering-Institute, in Kharkov, S.U.,
   visited the Dept. P-V on January 18-24, 1990.

4. Mr. R.A. Cardona
   representing the Executive Secretariat for Nuclear Affairs of the Ambassy of Cuba, located in Prague, Czechoslovakia,
   visited the Dept. P-V on January 29, 1990.

5. Dr. V.I. Tereshin
   from the Kharkov Physico-Technical Institute in Kharkov, S.U.,
   visited the Dept. P-V on Frebruary 26 - March 5, 1990.

6. Prof. Shunji Ido
   from the Department of Electrical Engineering, Saitama University in Shimo-Ookubo, Japan,
   visited the Dept. P-V on June 7, 1990.

7. Mr. Mashisa Ishine
   representing the Japanese Atomic Agency,
   visited the Dept. P-V on June 7, 1990.

8. Prof. Ryusuke Tsuji
   from the Department of Electrical Engineering, Ibaraki University in Hitachi, Japan,
   visited the Dept. P-V on June 7, 1990.

9. Mr. Munther A.R. Ibrahim
from the Iraqi Atomic Energy Commission in Bagddad, Iraq,
stayed of the Dept. P-V from December 19, 1989,
until June 16, 1990, for a scientific traning.

10. Dr. Asmus Petersen
from the Federal University in Hamburg, F.R.G.
visited the Dept. P-V on June 29, 1990.

11. Mr. Masahisa Ishine
from the Department of Electrical Engineering, Saitama University in Shimo-Ookubo, Japan,
stayed at the Dept.P-V from July 9 until July 20, 1990,
for a scientific training.

12. Dr. Vladimir A. Gulyaev
13. Mr.Borys Levkov
both from the Kurchatov Institute of Atomic Energy in Moscow,
S.U., visited the Dept. P-V on August 27-30, 1990.

14. Dr. Josef Rembser
from the Federal Ministry for Research and Technology
in Bonn-Bad Godesberg, F.R.G., visited the Dept. P-V
on September 3, 1990.

15. Mr. Yu. Istomin
16. Mr. V. Chernobrovin
17. Mr. R. Yermolov
18. Mr. V. Markov
19. Mr. V. Yeremkin
all from the Scientific-Research Institute of Electro-Physical
Equipment in Leningrad, S.U., visited the Dept. P-V
on September 15-22, 1990.

20. Prof. Giorgio Brianti
from the European Organization for Nuclear Research in Geneva,
Switzerland, visited the Dept. P-V on October 26, 1990.

21. Dr. Bucur Novac
22. Mr. Ion Tiseanu

both from the Institute for Atomic Physics in Bucharest, Romania, stayed at the Dept. P-V from November 27 until December 5, 1990, for a scientific training.

23. Dr. V.S. Koidan
24. Dr. E. Simonov

both from the Institute of Nuclear Physics in Novosibirsk, S.U., visited the Dept. P-V on December 6, 1990.

25. Dr. W.A. Gulyaev
26. Dr. B.S. Levkov

both from from the Kurchatov Institute of Atomic Energy in Moscow, S.U., visited the Dept. P-V on December 10-16, 1990.

8. LIST OF STAFF.

8.1. Scientific Staff

1. Appelt Jacek, Ph.D.
2. Baranowski Jarosław, M.Sc.
3. Bielik Mirosław, Ph.D
4. Brandt Szymon, M.Sc.E.E.
5. Gębalski Stanisław, M.Sc. - employed until Jan. 1990.
6. Gryziński Michał, Ph.D. - Assoc. Prof. - Head of Division.
7. Horodeński Andrzej, M.Sc.E.E.
8. Jakubowski Lech, Ph.D. - on leave of absence until May 1990.
9. Jerzykiewicz Andrzej, Ph.D. - Assoc. Prof. - Head of Division.
10. Kocięcka Krystyna, M.Sc.E.E.
11. Kociński Lech, M.Sc.E.E.
12. Komar Włodzimierz, M.Sc.
13. Kowalski Marian, M.Sc.
14. Kuciński Jacek, M.Sc. - on leave of absence until Dec. 1990.
15. Langner Jerzy, Ph.D. - Deputy Head of Department.
16. Nawrot Witold, M.Sc.
17. Pawłowicz Wiesław, Ph.D.
18. Przybylski Krzystof, M.Sc.
19. Rabiński Marek, Ph.D.
20. Rydygier Edward, M.Sc. - employed until August 1990.
21. Sadowski Marek, D.Sc. - Professor - Head of Department.
22. Składnik-Sadowska Elżbieta, Ph.D.
23. Szydłowski Adam, Ph.D.
24. Wlazło Mariusz, M.Sc. - employed until November 1990.
25. Żebrowski Jarosław, M.Sc.E.E.

8.2. Engineers

1. Borowska Elżbieta, M.Sc.E.E.
2. Czaus Krzysytof, Eng.
3. Ćwiek Ewa, Eng.
4. Frejlak Wojciech, M.Sc.
5. Mirowski Robert, M.Sc.M.E.
7. Polak Wawrzyniec. Eng.

8. Puchalski Zygmunt, M.Sc.E.E.
9. Stanisławski Jacek, M.Sc.E.E.
10. Witkowski Jan, Eng.
11. Wyszyński Władysław, Eng.
12. Ziemski Waldemar, M.Sc.

8.3. Technicians

1. Cywiński Krzysztof
2. Czajkowska Joanna
3. Gątarczyk Krzysztof
4. Gniadek Krzysztof
5. Grzeszczyk Zdzisław
6. Jankowski Marek
7. Jęda Andrzej
8. Karpiński Paweł
9. Kasperski Krzysztof
10. Kołakowski Bernard
11. Kołnierzak Ryszard
12. Koszewski Grzegorz
13. Kraszewski Antoni - employed until December 1990.
14. Królik Jerzy
15. Kuk Mirosław
16. Kwiatkowski Marek
17. Machalski Piotr
18. Michalik Krzysztof
19. Michalik Wiesława - partial emloyment until June 1990.
20. Nawrocka Halina
21. Pijanowski Wojciech
22. Rybicki Ryszard
23. Skwara Sławomir - employed until July 1990.
24. Staszkiewicz Bogdan
25. Trembicki Andrzej
26. Wiraszka Andrzej
27. Zagórski Jerzy

8.4. Workshop

1. Jędrzejczyk Marek
2. Szoch Sławomir
3. Niewiadomski Andrzej

8.5. Administration Staff

1. Gawrońska Alicja
2. Presner Franciszek
3. Salamońska Anna

Wydaje Instytut Energii Atomowej - OINTEA
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