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CHINA NUCLEAR SCIENCE AND TECHNOLOGY REPORT

国际原子能机构小型聚变装置研讨会（文摘）

IAEA TECHNICAL COMMITTEE MEETING ON RESEARCH USING SMALL FUSION DEVICES (ABSTRACTS)

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RUSFD '99

IAEA Technical Committee Meeting on Research Using Small Fusion Devices

18～20 October 1999

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ABSTRACTS

SOUTHWESTERN INSTITUTE OF PHYSICS

CHENGDU, CHINA

前　言

国际原子能机构关于利用小型聚变装置进行研究的技术委员会会议（TCM/RUSFD）已于1999年10月18日至20日在中国成都召开。会议收到论文41篇，内容涉及环形系统、螺旋系统、等离子体聚焦、诊断系统、理论和模型、改进等离子体约束、数字模拟、创新概念等。中国西南物理研究院（SWIP）承担了会议的组织工作。《中国核科技报告》编辑部编写了该中文前言，对文摘内容进行了编辑。

FOREWARD

The IAEA Technical Committee Meeting on Research Using Small Fusion Devices

October 18~20, 1999, Chengdu, P. R. China

In the field of fusion research small fusion devices are still indispensable for innovation and / or as alternatives for main projects such as tokamaks and laser fusion which are under large scale development. The IAEA Technical Committee Meeting on Research Using Small Fusion Devices, formerly called the IAEA TCM on Using Small Tokamaks, was continued from the 1st meeting at Budapest in 1985 to the 12th meetings at Shonan Village (Japan) in 1998. This year, we would like to have the 13th TCM/RUSFD for three days from Monday, October 18, through Wednesday, October 20, 1999, in Chengdu, P. R. China. The local organizer will be the Southwestern Institute of Physics (SWIP).

The objective of the meeting is to provide a forum for discussion of approaches to fusion research based on small- and medium-scale devices, such as small tokamaks, reversed field pinches (RFP), helical devices, linear/discharge machines, etc. The meeting will also cover topics on non-magnetic confinement devices, devices using beams or lasers and new trends or innovation concepts for fusion research. The format of the meeting will include several review talks, a number of oral talks and poster sessions. Much time will be left for discussions.

The program of this meeting will be divided to the following topics:

- Toroidal Systems
- Helical Systems
- Plasma Focus
- Other Devices
- Diagnostic Systems
- Theory and Modeling
- Improving Confinement
- Numerical Simulation
- Innovative Concepts
- Others

Following persons are Members of the Programme Committee:

Gribkov	Russia	Plyusnin	Ukraine
Stoeckel	Czech Republic	Steward	US Mission,Vienna

Deng***	P. R. China	Masoud**	Egypt
Sakanaka	Brazil	Kaw*	India
Shimada	Japan	Morris	England
Schneider	IAEA		

*Prof. Kaw: Chairman of the Programme Committee

**Prof. Masoud: Vice-Chairman of the Programme Committee

***Prof. Deng: Chairman of the Local Organizing Committee

The conference is organized by Southwestern Institute of Physics, Chengdu, Sichuan, P. R. China.

The organizers of this conference are:

Local Organizing Committee:

Prof. Yan Jiancheng, Southwestern Institute of Physics, P. R. China

Prof. Deng Xiwen, Southwestern Institute of Physics, P. R. China

Prof. Wan Yuanxi, Institute of Plasma Physics, Academia Sinica, P. R. China

Dr. Dai Bin, Southwestern Institute of Physics, P. R. China

Prof. Wang Kongjia, Institute of Plasma Physics, Academia Sinica, P. R. China

IAEA Scientific Secretary: Dr. Ursula Schneider

PROGRAMME AND TIME TABLE

18 Oct. (Mon.)

Opening Session (chairperson Dr. Qian)

9:50—10:30	Opening Ceremony	Deng Xiwen U. Schneider

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11:00—11:30	Small Spherical Focus and Tours	M. M. Masoud
11:30—12:00	RF Plasma Discharge Conditioning and Antenna Performance in URAGAN-3M	V. V. Plyusnin

Session II (chairperson Dr. Plyusnin)

14:30—15:00	Recent HL-1M Experiment Progress	E. Y. Wang
15:00—15:30	Using Neural Networks to Forecast Tokamak Plasma Disruptions	Alvaro Vannucci
15:30—16:00	Design and Testing of Twelve Channel Heterodyne Radiometer for the SINP-Tokamak	Ratneswar Ray

Session III (chairperson Dr. Vannucci)

16:30—17:00	MHD Behavior Observation by Mirnov Coils on the CT-6B Tokamak	Khorshid Pejman
17:00—17:30	Analysis of Charge Exchange Spectrum During Lower Hybrid Current Drive on HT-7 Tokamak	S. X. Liu
17:30—18:00	Experimental Study of a Small Gas-Puff Z-Pinch Plasma Device	C. M. Luo

19 Oct. (Tue.)

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9:00—9:30	Exploration of High Performance Scenarior in HL-2A	Q. D. Gao
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10:30—11:00 A New Fuelling Method for Tokamak — L. H. Yao

11:00—11:30 Experimental Study on LHCD Efficiency in HT-7 Tokamak — B. J. Ding

11:30—12:00 The Direct Measurements of the Plasma Electric Potential by Heavy Ion Beam Probe on T-10 Tokamak — B. L. Ling

Session VI (chairperson Dr. Ohkuni): Poster Session (14:30-16:00)

Session VII (chairperson Dr. Gusakov): Poster Session (16:30-18:00)

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Excitation ExperimentsAlfven Eigen Modes by AC Current Flowing Along the Magnetic Field Line in CHS — G. Matsanaga

Characteristic Features of Sawtooth Crash in CHS — Takagi Shoji

Study of The Ohmic Plasma Density Limit in HL-1M — Y. Zhou

Features of The Electron Energy Balance in High Density Ohmic H-Mode in TUMAN-3M Tokamak — Alexander Tukachinsky

Upper Hybrid Resonance RADAR Scattering Diagnostics of Small Scale Turbulence in FT-1 Tokamak — Evgeniy Z. Gusakov

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The Runaway Generation And Disruptive Instability in The ISTTOK Tokamak — V.V.Plyusnin

Plasma Coaxial Discharge for Thin Film Deposition — H.A.E1-Tayeb

Miniature Coaxial Plasma Injector for Diagnostic by Beam Plasma Interaction — H.A.E1-Tayeb

An Analytical Analysis of Relaxation States in Toroidal Plasma with a Coaxial Helicity Injection — D. Zhou

Scaling of Electron Kinetic Energy Confinement for Ohimc Discharges in HL-1M — J. Y. Cao

CCD Photography of Pellet Ablation in HL-1M Tokamak — Y. J. Zheng

Preliminary Results From the TCABR Tokamak — Ivan Nascimento

The Research Evolution of Reversed Field Pinch Plasma on SWIP-RFP Device — Q. Li

Two-Dimension Simulations of Plasma Transport in High Recycling, Divertor Tokamak Scrape-off Layer — Q. L. Li

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11:30—12:00	Generalized Gyrokinetics in Tokamaks	Z. T. Wang

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15:00—15:30	3 mm Fast-scanning Microwave Heterodyne Radiometer for ECE Measurements on HT-7 Superconducting Tokamak	S. Y. Zhang
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Small Spherical Focus and Tours

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Small Spherical Focus

A spherical focus has been designed recently which for intense X-ray production. The geometry of the system consists of two concentric hemi-spheres insulated from each others by ceramic disc and with two ports at each. Theoretical simulation of the current sheath dynamics shows a simple relation where only radial phase exist. The focus density was one order higher than Mather type which the plasma temperature is in the same order. The construction, theory, and test results are discussed in detail.

Small Spherical Tours

A small spherical simple and low cost torus has been deigned and constructed to work in the Tokamak regime. It consists of two cylinders 20 cm length fixed with two electrodes at ends. The ohmic coil is air core derived by 10 kJ capacitor bank which can produce 10 kA plasma current. The toroidal field is 0.5 T, and the vertical field is 0.01 T. The two electrodes are used for linear discharge for the ignition of the plasma current and cleaning the walls. The first tests showed that the system is reliable to work in different regimes up to the tokamak one.

CN0101710

RF Plasma Discharge Conditioning and Antenna Performance in Uragan-3M

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The RF method for plasma creation in the frequency range below the ion cyclotron frequency is the typical method used in plasma heating and confinement experiments in the Uragan-3M torsatron. Different antenna systems were elaborated in order to provide the creation of plasma with the density up to $(2\sim3)\times10^{13}$ cm^{-3} and further investigation of plasma heating and confinement[1]. An advantage of chosen plasma production method is that the same antenna without change of RF transmitter (heating) frequency ω_0 was applied for generation of plasma used for conditioning of inner metallic surfaces in vacuum chamber of Uragan-3M[2]. The similar approach based on the Uragan-3M experience was used recently in the TEXTOR-94[3] and TORE SUPRA[4] tokamaks where plasma for conditioning was produced by the same antenna system used in plasma heating experiments.

The RF Plasma Discharge Conditioning experimental scheme in Uragan-3M is realized at the decreased confining magnetic fields ($B_0 = 0.01\sim 0.1$ T) kept under the steady-state regime. The plasma was produced at the wide frequency range $\omega_0/\omega_{ci} \cong 3\sim30$, i.e at the high harmonics of the ion cyclotron frequency and helicon frequency ranges. The production of plasmas in this frequency range is the object of extended interest now, because of its attractivity for powerful plasma sources for fundamental plasma fusion studies and plasma technology processes. In the Uragan-3M RF PDC experiments at this frequency range the plasma density values obtained were widely varied depending on antenna coupling efficiency.

This report presents the results of numerical modeling of antenna coupling efficiency at the plasma parameters obtained in RF PDC experiments in the Uragan-3M torsatron. The results obtained were qualitatively compared to experimental data for better understanding of the antenna performance for RF PDC in this device.

Rferences

[1] V.V. Plyusnin et al. In: Joint Conference of 11th International Stellarator Conference and 8th Int. Toki Conference on Plasma Physics and Controlled Nuclear Fusion, Toki, Japan, 1997, Journal of Plasma and Fusion Research (JPFR Series, Vol.1)

[2] N.I. Nazarov, V.V. Plyusnin, et al. Plasma Physics Reports (Fizika Plasmy - Sov. Journal of Plasma Physics), 13 (1987) 1511-1515.

[3] A.I. Lyssoivan et al. 23rd EPS Conference on Controlled Fusion and Plasma Physics. Kiev, 1996, Vol.20C.

[4] Lyssoivan et al. 26th EPS Conference on Controlled Fusion and Plasma Physics, Maasricht, 1999, Vol.23J, 737

Recent HL-1M Experiment Progress

E. Y. Wang and HL-1M Team

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This report presents experimental progress of HL-1M made during last years. An overview of the experimental studies including plasma control, wall conditioning, new fueling technique, low hybrid current drive (LHCD), low hybrid wave (LHW) ion heating, based H-mode, neutral beam injection (NBI) heating, ion cyclotron resonance heating (ICRH) and shear reversed experiments will be given.

In 1993 and 1994, HL-1 was modified to HL-1M by replacing the vacuum chamber. HL-1M is a circular cross-section tokamak with R = 1.02 m, a = 0.26 m, B_t < 3 T, I_p < 350 kA, a pulse duration of up to 4 s, $n_e = (1\sim8)\times 1019\ m^{-3}$. The goal of the HL-1M programme is to conduct high power auxiliary heating (NBI power of about 1 MW, ICRH power of about 1 MW) and current drive (LHCD power of > 1 MW) experiments in order to develop the physics and technology basis for the next tokamak, HL-2A, which is a modification of the ASDEX machine of the Max-Planck-Institut at Garching, Germany.

Using Neural Networks to Forecast Tokamak Plasma Disruptions

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A feed-forward neural network with two hidden layers was used in this work to forecast major and minor disruptive instabilities in tokamak discharges. Using alternatively experimental magnetic data and soft X-ray signals, the neural net was trained with one or two disruptive plasma discharge, and a different disruptive discharge was used for validating the training process. After being properly trained

the networks, with the same set of weights, was then used to forecast disruptions in other different plasma discharges. Using soft X-ray data measured in the TEXT tokamak, for example, it was observed that the neural net was able to predict the occurrence of a disruption more than 3 ms in advance. This time interval is almost three times longer than the one previously obtained when magnetic signal from a Mirnov coil was used to feed the neural networks with.

This predictive capability may be even more useful for large tokamaks which have long time scales of plasma evolution because it opens up the possibility of using feed-back controlled auxiliary systems such as electron cyclotron heating, neutral beam, pellet injection, external magnetic fields, etc., to avoid the occurrence of the upcoming disruption or at least to minimize its harmful effects.

Design and Testing of Twelve Channel Heterodyne Radiometer for the SINP-Tokamak

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A twelve channel radiometer, in the frequency range of 75～110 GHz, has been designed and constructed for the SINP-Tokamak to diagnose second harmonic X-mode electron cyclotron emission (ECE). This frequency range covers approximately 80% of the plasma cross section in case of a magnetic field of B = 1.5 T. For the maximum field of the SINP-Tokamak B = 2.0 T, about 50% is covered. The bandwidth of each channel is 1 GHz, which yields a spatial resolution of $\delta R/R$ = 1.4% at the low field side and 0.9% at the high field side.

The ECE radiation is received by a single horn antenna with a gain of approximately 30 dB. To increase the spatial resolution perpendicular to the line of sight, a focusing lens is employed. The incoming radiation power is split into two branches by a 3 dB coupler. Before down conversion of the input spectrum, the upper and the lower side band is selected respectively by means of a highpass and a low pass filter. Behind the filters, identical components are employed. The local oscillator frequency is 92 GHz for both mixers. The IF frequency range after down conversion is 2 to 18 GHz. The IF spectrum is amplified by two amplifiers with a total gain of approximately 60 dB. The output of these amplifiers is split into 6 branches. After frequency selection by means of bandpass filters, the received power is detected by Schottky diode detectors. After video amplification and filtering, the data is recorded by an ADC with 1 MHz sampling rate. Video lowpass filters having cut-off at 300 kHz is used to avoid aliasing.

The radiometer has been calibrated with a high temperature blackbody radiator. The radiation was chopped by a 100 Hz chopper. The output signal of the radiometer was averaged by means of a digital oscilloscope, with a maximum integration time of 1000 sweeps. The effective input noise temperature for the radiometer channels is found to be in the order of 0.1 eV. The linear regime of operation extends up to an input power which corresponds to an electron temperature of approximately 200 eV. Above this temperature the 1 dB compression point of the Schottky diode detectors is exceeded and the IF gain should be reduced. This can be easily done by incorporating appropriate attenuator behind the IF amplifiers.

CN0101714

MHD Behavior Observation by Mirnov Coils on the CT-6B Tokamak

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Evidence of magnetic islands in Tokamak plasmas is given by the external magnetic field fluctuations. In the CT-6B Tokamak MHD activity is detected by a poloidal array of external Mirnov coils. The beginning of MHD oscillation behavior varies by changing plasma displacement and vessel pressure. During current rise, flat and ramp down phases, polar plots of Mirnov array signals are compared with safety factor $q_a=5a^2B_t/RI_p$ near limiter that it is calculated by two different plasma radius (a) and (a-dx).

Fourier analyses in the time and spatial domains were performed to obtain the mode number and their frequencies. A study of 3-Dimension plotting the time evolution of poloidal angular dependence of the amplitude of perturbed magnetic field shown that there are several kind of mode by different frequencies, high and low frequency, so that they indicate different kind of island. These islands located inner and outer of a magnetic surface and they rotate by different direction. The modes are coupled with together and sometimes they are in lucked-mode.

Reference

[1] Mirnov, S.V., Semenov, I.B., in Plasma and Controlled Nuclear Fusion Research (Proc. Int. Conf. Berchtesgaden, 1976) 1, IAEA, Vienna (1977) 291.

[2] Karger, F., Lackner, K., Fussmann, G. and et. al., ibid, 267.

[3] Granetz, R.S., Hutchinson, I.H., Overskei, D.O., Nuclear Fusion, Vol.19, No.12 (1979) 1587.

[4] Kim, S.B., Kochanski, T.P., Snipes, J.A., FRC Report #256 (1984).

[5] Chen, J.Y. and et. al., FRC Report #387 (1991).

[6] Kluber, O., Zohm, H., Bruhns, H., Gernhardt, J., Kallenbach, A., Zehrfeld, H.P., Euratom-Association, IPP III/140 (1989).

[7] Harley, T.R., Buchenauer, D.A., Coonrod, J.W., McGuire, K.M., Nuclear Fusion, Vol.29. No.5 (1989) 771.

[8] Kaita, R., Batha, S.H., Bell, R.E. and et. al., Nuclear Fusion, Vol.38, No.6 (1998) 863.

Analysis of Charge Exchange Spectrum During Lower Hybrid Current Drive on HT-7 Tokamak

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This paper presents the experimental results by charge-exchange fast neutral particle measurements with neutral particle energy analyzer (NPA) in lower hybrid current drive (LHCD) experiments, which firstly show ion heating of LHCD on HT-7 superconducting tokamak. The LHCD experiments on HT-7 tokamak were carried out with the following paramenters: B_t=1.8 T, I_p=110~150 kA, n_e=(0.8~2)$\times 10^{13}$ cm^{-3} . The lower hybrid wave (LHW) had a pulse duration of 360ms and power of about 300 kW with an peak of parallel refractive index of $N_{//}$ = 2.9.

The experimental data from the measurements of NPA consists of the neutral particle fluxes and particle energy distribution. The ion temperature is determined from the slope of the neutral particle energy spectrum. We have observed the enhanced charge-exchange neutral particle signal on various energy channels in the 0.5~6.0keV range during LHCD. The energy spectrum shows existence of the high energy ion tail during LHCD. The ion tail is extended up to at least 14 keV. The bulk ion temperature is about 0.95 keV obtained from the slope of the energy spectrum in the energy range of 0.8~4 keV. The ion temperature is increased by 0.4 keV after the onset of LHCD. The tail- temperature i.e. the straight slope defined by the higher energy particles (E6 keV) is 10 keV.

Experimental Study of a Small Gas-Puff Z-Pinch Plasma Device*

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Experiment was carried out on a small gas-puff Z-pinch plasma device with capacitor bank of 16 μF and charging voltage 22 kV. Discharge current was measured by Rogowski coil. A compact Thomson ion energy analyzer was installed in the discharge chamber for determining the energy spectra of ion beam emitted from the Z-pinch plasma. The energy spectra of Argon ion beams with single, double and triple charges were determined using the analyzer. A Mach-Zehnder laser interferometer was installed to measure the electron density and the movement of Z-pinch plasma. The electron density of the plasma just before pinch instant is larger than $9.00 \times 1018/cm^3$, the corresponding radius and the pinch velocity of the plasma are 1.42 mm and 1.86 cm/μs, respectively. The yield and the time variation of X-ray emitted from the pinch plasma were also measured.

CN0101717

β_N Studies in Different Modes of TUMAN-3M Operation

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The ratio of the plasma kinetic pressure to the magnetic field pressure–β determines efficiency of plasma confinement in a magnetic configuration. Values of β_T in a tokamak are restricted by the ideal MHD limit (Troyon limit). The limit establishes correlation between maximum values of β_T (expressed in %) and parameter I/aB (MA, m, T). The maximum values of $\beta_N = \beta_T/(I/(aB_T))$ are close to 3.5 in a tokamak with conventional geometry. In the experiments with strong crossection shaping and powerful auxiliary heating β_N close to 5 have been obtained.

In this paper the results of experimental study of a possibility to increase β_T and β_N in a circular crossection tokamak without auxiliary heating are presented. The experiments were performed in the TUMAN-3M tokamak. The device has following parameters: R_0 = 0.53 m, a_l = 0.22 m (circular limiter configuration), $B_T \leqslant 1.2$ T, $I_p \leqslant 175$ kA, $\overline{n_e} \leqslant 6.2\times10^{19}$ m^{-3}. Stored energy quantities were measured using diamagnetic loops and compared with calculated from kinetic data obtained by Thomson scattering and microwave interferometry. Measurements of the stored energy and of the β were performed in ordinary Ohmic regime, in Ohmic H-mode and in the scenario with fast Current Ramp-Down in Ohmic H-mode. The β values in boronized vessel were compared with that ones obtained before boronization.

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Exploration of High Performance Scenarios in HL-2A

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The HL-2A tokamak (R=1.64 m, a=0.32~0.4 m, k_x=1.3, δ_x=0.5, B_T=2.8T, I_p=0.48 MA) is under construction in SWIP. The main objectives of the project are to produce more adaptable divertor configuration to study energy exhaust and impurity control, and study enhanced core plasma confinement by profile control and moderate plasma shaping. Here we explore some enhanced confinement scenarios expected in operation with combined auxiliary heating and non-inductive current drive in HL-2A.

The time dependent TRANSP code is used to model the realistic reversed magnetic shear operation in HL-2A. We inject 3.0 MW neutral beam into a target plasma with gradually peaking density profile ($n_e(0)/\langle n_e \rangle$=1.7~3.4). As plasma β rising, RS configurations are formed with the minimum $q(q_{min})$ evolving from q_{min}>3.0 to q_{min} <2.0 and q_{min} being localized at $r_{min}/a \approx 0.3$. Excessively peaked pressure profile (up to $p(0)/\langle p \rangle \geqslant 5.5$) and significant bootstrap current fraction characterize these RS configurations. MHD instability analysis for the simulated discharge indicates that the low-n modes located in the low shear region around the shear reversal point are developed, and the large pressure gradient in the central negative shear region drives resistive interchange modes.

To avoid excessive peaking pressure profile and sustain the RS operation towards steady state, off-axis current drive with LHW at 2.45 GHz is used to control the current profile. The LHCD simulation utilizes a toroidal ray-tracing calculation and a parallel velocity Fokker-Planck calculation for the interaction of the waves and particles. The LHCD package is in conjunction with the TRANSP code to get the driven current in a dynamic case. As the ion energy transport drops to roughly the neoclassical level in RS discharges, the ion thermal diffusivity model is assumed in terms of neoclassical transport enhanced by η_i turbulence which is responsible for the transport outside the shear reversal region. The electron energy transport is based on the Rebut-Lallia-Watkins critical electron temperature gradient model. When the 0.5 MW LHW power injects, a stationary RS discharge is formed after a 0.1~0.2 s transitional phase. The stationary RS discharge with $r_{min}/a \approx 0.6$ and $q_{min} \approx 2.5$ is sustained until the LHW is terminated. During the stationary RS phase a self-consistent ITB (Internal Transport Barrier) appears on the ion temperature profile, implying the enhanced ion energy confinement.

Full-wave simulations of the ICRF heating used to obtain high β scenarios will also be shown. One heating option is off-axis D(H) minority heating at B_T=2.2 T using 30 MHz ICRF source. Another option would rely on central $D(^3He)$ minority heating at B_T=2.8 T using 28 MHz source.

Recent Developments in Heavy Ion Beam Probe Diagnostics

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Heavy Ion Beam Probe diagnostic (HIBP) is a non-perturbative local multipurpose diagnostics that allows us to monitor the temporal evolution of 2D distributions of several plasma parameters, such as the electric potential Φ, the density n, the poloidal field B_p and the electron temperature T_e. HIBP allows us to measure the fluctuations Φ, B_p and n, which may cause the anomalous transport. The investigation of the plasma electric potential can be provided by HIBP only.

The importance of the radial electric field for the plasma confinement and equilibrium in the fusion devices with magnetic confinement is well recognized now. It is expected that the electric field can help us to understand the underlying mechanisms that forms transport processes in the plasma. The study of the electric field in the L-H transition and H-mode is the most desirable target for the experimental research now.

An advanced HIBP diagnostic was developed and manufactured for TJ-II stellarator based on the utilization of two different detector schemes: MCA detector and 30° Proca-Green electrostatic energy analyzer. This innovative design aims to spread and improve the HIBP capabilities in simultaneous measurement of plasma potential, density and electron temperature profiles as well as their fluctuations.

Now this diagnostic equipment put in operation. The energies of probing ions (Cs^+, Tl^+) are in the range of 80~200 keV, intensity up to 100 μA. A detection technique is yielding in order of magnitude increase in the sensitivity of analyzer to beam energy measurements (Φ) have been demonstrated.

The Heave Ion Beam Probe (HIBP) diagnostics on T-10 tokamak (R=150 cm, a=30 cm) was modified to measure the local values of the plasma potential in ECRH plasma. The Tl^+ ion beam with the energy up to 250 keV and intensity about a few tens of μA was used in experiments. The clear falling down the potential in range of −200 ≒ −600 V was observed during the phase of the improvement plasma confinement in the outer region with respect to EC resonance. The fall down of potential accompanies the decrease the intensity of D_α. The time evolution of spatial profiles was also observed.

A New Fueling Method for Tokamak —Supersonic Molecular Beam Injection

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A new method of gas fueling——pulsed supersonic molecular beam injection (MBI) has been introduced in the HL-1M tokamak. Its performances are something between the gas puffing (GP) and the pellet injection. The mean velocity of well collimated hydrogen beam in the vacuum chamber is above 500 m/s. With penetration depth of hydrogen particles (1/e decay) beyond 10 cm, the ramp-up rate of electron density $d\bar{n}_e/dt$ was as high as 2.9×10^{20} $m^{-3}\cdot s^{-1}$ with steady state.

In recent experiment, hydrogen MBI has been successfully performed in the HL-1M tokamak ohmic heating plasma during the period of the plasma current slow ramp up or second ramp up. The resulted plasma density limit reaches $\bar{n}_e=8\times10^{19}$ m^{-3} with reduced impurity concentration and exceeds the density limit with GP plasma for about $2\times10^{19}\,m^{-3}$ under the same operation conditions. The upper density end of the linear ohmic confinement regime has an apparent increment of 1.5 under the conditions of slowly and larger plasma current. The profile peaking factor Q_n after MBI reaching a maximum value is larger than 1.65. With MBI the energy confinement time τ_E measured by dimagnetism is 10%~30% longer than that with GP under the same other discharge condition.

If there exist a mixture of a small fraction of impurity (heavy) particles, the gases is expanded through the nozzle as a result of the many collisions, the impurity particles will be accelerated to a speed nearly equal to the working (light) particles. So the MBI is not only a purer and high efficiency hydrogen gas fuelling method than the conventional GP for its well-collimated features and the reduction of the edge recycling, but a better gas doping method as well. It may be developed into a useful method for the edge plasma cooling and the transport research of impurity particles.

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Experimental Study on LHCD Efficiency in HT-7 Tokamak

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Lower Hybrid Current Drive (LHCD) experiments on HT-7 Tokamak have been carried out by scanning the following two parameters: central line averaged electron density $(0.5\sim2.0)\times10^{19}\,\mathrm{cm}^{-3}$ and toroidal magnetic field (B_t=1.62~2.0 T). The dependence of current drive efficiency on these parameters has been studied and the experimental curves of current drive efficiency as a function of and B_t have been obtained. From these experimental curves, it can be seen that lower hybrid current drive efficiency increases with the increase of toroidal magnetic field but, there exists an optimized density regime where highest current drive efficiency can be obtained. The experimental results are analyzed and interpreted through theoretical current drive efficiency. The results are also consistent with numerical simulation by using a ray-tracing code, where A is the parameter related to plasma energy and $N_{//}$ is the parallel refractive index. The results show that current drive efficiency is mainly affected by wave accessibility condition and impurity radiation. As a matter of fact, the experiments on HT-7 shows that the competition of these two factors determines current drive efficiency.

The Direct Measurements of the Plasma Electric Potential by Heavy Ion Beam Probe on T-10 Tokamak*

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The Heavy Ion Beam Probe (HIBP) diagnostics on T-10 tokamak (R = 150 cm, a = 33 cm) was modified to measure the local values of the plasma potential in ECRH plasma (B_0 = 2.2~2.5 T, I_{pl} = 75~280 kA). The Tl^+ ion beam with the energy up to 240 keV and intensity about a few dozens. The clear fall of potential in the range of −200 ~ −600 V was observed during the phase of the improvement plasma confinement in the outer region with respect to EC resonance. The fall down of potential accompanies the fall of Da and the density increase. The time evolution of spatial profile demonstrates the formation of the thin (about 1 cm) area near the limiter with strong Er (~300 V/cm), that proofs the H-mode observation in a circular limiter tokamak.

The Correlation Between Energy Deposition of the Lower Hybrid Wave and Hard X-Ray Radiationon Ht-7 Tokamak

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During lower hybrid current drive, a non-Maxwellian current carrying tail of energetic electron is created by the radio frequency (RF) waves. The electron tail is formed through Landau damping of the lower hybrid wave. This high-energy tail emits a continuum bremsstrahlung radiation due to collisions between the tail electrons and the bulk plasma ions and electrons (the electron-ion bremsstrahlung is dominant). A lot of important information about the high-energy electrons and the physical mechanism of LHW propagation and absorption in plasma can be obtained from the hard X-ray measurement.

A seven-channel NaI (Tl) array has been installed, which measured the hard X-ray emitted perpendicular to the magnetic axis though a horizontal window on HT-7 tokamak during LHCD, of which the energy ranged from 20 keV to 500 keV. The measurement results indicate that the wave with small $\Delta\Phi$ deposit its energy primarily within the inner half (r/a<1/2) of the plasma column, while the wave with larger $\Delta\Phi$ mainly deposit its energy in the outside of the plasma column. The hard X-ray radial profile is more peaked in high plasma density and become broad in lower plasma density. The phenomenon is consistent with the accessibility condition.

X-Ray and Corpuscular Emission from Hot-Spots in Plasma-Focus Discharges

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A dense magnetized plasma, as produced by high-current discharges of the Plasma-Focus (PF) type, can form locally very small (tiny) regions – so called "hot-spots" – characterized by extreme values of basic parameters. Within such hot-spots the electron concentration can reach 10^{20}~10^{21} cm^{-3}, and electron temperature can exceed 1 keV[1]. Detailed observations, as performed for PF-discharges under different experimental conditions, showed that dimensions of the hot-spots are of the order of micrometers, and their life-time varies from several to about dozen nanoseconds.

Numerous studies proved that such high-density and high-temperature plasmas, as those forming the hot-spots, are sources of intense X-ray pulses[2]. It was shown that the hot spots are formed in a determined sequence, starting near the electrode ends, and later on appearing at a larger distance, when a current-sheath layer collapses the discharge axis[3]. There were also observed pulsed electron- and ion-streams emitted mostly along z-axis, but in opposite directions[4]. More detailed X-ray measurements, performed with two crystal spectrometers simultaneously[5], demonstrated the selected X-ray lines reveal different polarization. This effect can be explained by a non-maxwellian distribution of electron velocities and the appearance of directed electron beams, as well as strong local electric- and magnetic-fields.

The main aim of this paper was to present a concise review of recent studies of the non-linear phenomena described above. The considered studies have been performed with PF facilities operated at IPJ in Swierk, Poland, but within a frame of an extensive international collaboration.

References

[1] L.Jakubowski, M.Sadowski, E.O.Baronova; EXPERIMENTAL STUDIES OF HOT-SPOTS INSIDE PF DISCHARGES WITH ARGON ADMIXTURES, Proc. 1996 Int.Conf. on Plasma Phys. (Nagoya 1996), Pt 2, p.1326.

[2] L.Jakubowski, M. Sadowski, RECENT OBSERVATIONS OF X-RAYS AND E-BEAMS IN PLASMA-FOCUS DISCHARGES, 26th European Physical Society Conference on Controlled Fusion and Plasma Physics, 1999, Maastricht, The Netherlands, June 14-18, 1999.

[3] L.Jakubowski, M.Sadowski; STUDIES OF HOT-SPOTS AND THEIR CORRELATION WITH OTHER PHENOMENA IN PF-TYPE DISCHARGES, Proc. 22nd EPS Conf. CF&PP (Bournemouth 1995), Pt.2, p.181.L.Jakubowski, J.Baranowski, M.Sadowski and J.Żebrowski, ION BEAM MEASUREMENTS WITHIN MAJA-PLASMA-FOCUS FACILITY, J. Tech. Phys. 40, 1, (1999) 137.

[4] L. Jakubowski, M. Sadowski, E.O. Baronova, V.V. Vikhrev, STUDY OF X-RAY POLARIZATION AND E-BEAMS GENERATION DURING HOT-SPOTS FORMATION IN PF-DISCHARGES, Fourth International Conference on Dense Z-Pinch, Vancouver 1997 pp. 443-447.

[5] F.B.Rosmej, E.O.Baronova, V.V.Vikhrev, L.Jakubowski, M.Sadowski, O.N.Rosmej and A.M.Urnov, INVESTIGATION OF NON-MAXWELLIAN ELECTRONS IN DENSE PINCHING PLASMAS, J. Tech. Phys. 40, 1, (1999) 153.

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Plasma Focus Fusion Research in Zimbabwe

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This work describes in part the results of a simplified three stage model of a plasma focus device in terms of the dimensions, filling gas pressure and charging voltage. An optimum pinch radius ratio of 0.03 to 0.4 was realized. The model showed that final axial velocity determines the initial inward radial velocity. The second part is the design, fabrication and characterization of a plasma focus device which has the inner electrode negatively charged (−12 kV). The optimum operating

conditions of this plasma focus device were found to be in the pressure range between 0.5 and 2.0 mbar (1 bar=10^5 Pa), for all the gases tested and for an inner electrode length of 40 mm. The experimental results obtained with the device are presented. These results are being repeated (a) with Deuterium as filling gas in order to confirm focus action by measuring neutron yield; and (b) in the model a Negative Charging Voltage is used and calculations of the pinch radius ratio redone. Wax is used for shielding against neutron irradiation and a film badge is used to monitor the level of radiation exposure. This second set of results will be presented also.

Equilibrium State of the Plasma Focus

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In this paper equilibrium conditions of the plasma focus will be briefly reviewed and a possible mechanism of the plasma focus hot spot formation and it's impact on plasma focus fusion potential will be discussed. Among all controlled thermonuclear fusion devices, the fascinating device plasma focus yields a very high rate of neutron production, yields information on the processes of acceleration that produce the high-energy particles associated with even those found in cosmic rays and achieves energy flux densities beyond those reached even in nuclear explosions. It has been experimentally confirmed[1] that the spontaneously self-organized plasma stable, force-free, minimum-free-energy vortex filamentary structures of a Beltrami[2] morphology can spring into existence. The two types of the vortices, corotational and contrarotational, moving parallel and antiparallel to the background magnetic field, were experimentally observed in the current sheath of the plasma focus to be produced in pairs. Arrangement of the four relevant configurations field vectors, i.e. magnetic induction vector, mass velocity vector, vorticity vector and electric current density vector, in the vortex filament is so, that only in the very center of the filament the field vectors are directed in the axis direction. With increase of the distance from the filament center, the angle between the axis and the field vector becomes smaller and smaller. All fields in a vortex filament are arranged according to the same principle. Because in every point the magnetic induction vector is parallel to the current and vorticity vectors, the Lorentz force is locally everywhere in equilibrium with the Magnus force. Some of the filaments may survive to carry a large portion of the current all by themselves, becoming knotted in itself. It has been theoretically evaluated[3] that the degree of the mutual knottedness of the four relevant fields is direct proportional to the degree of the free-energy concentration in the plasma force-free configuration and opposite proportional to the plasma force-free volume inside which the vectors are knotted. From the last statement it can be concluded that prevention of the hot spots formation in the plasma focus is of the crucial importance for it's fusion potential.

References

[1] W.H. Bostick et al., Phys. Rev. A, 22(5), 1980, pp. 2211

[2] E.A. Beltrami, Hydrodynamic Conservations, Rendicoti del Reale Instituto Lombardo, Seria II, Tomo XXII, pp 121-130

[3] I.S. Lakicevic, Technical Committee Meeting on Research Using Small Fusion Devices (F1-TC-536-14), Tokyo, 1998, pp. 54

4 kJ Plasma Focus

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The work described in this paper is a combination of plasma focus electrical parameters and plasma sheath axial phase dynamics. 4 kJ plasma focus device of Mather type, is powered by two modules capacitor bank of 61.68 μF capacity, has been constructed for this course of study. The discharge takes place in helium gas with an operating pressure ranging from 0.5 to 1.5 Torr (1 Torr=133. 3224 Pa). The experiments are conducted with charging voltages changes from 8 to 12 kV.

In this work a number of diagnostic techniques were constructed. Discharge current, voltage, magnetic fields and common visible radiation are measured by Rogowsky coil, capacitor potential divider, magnetic probes and photomultiplier with light guide system respectively.

The experimental results of the plasma focus device electrical parameters for bank charging voltage, U_{ch} = 8kV and pressure p= 1 Torr, showed that, the maximum discharge current and voltage were 98 kA and 4 kV respectively. The total circuit inductance and resistance were 3.22×10^{-7} H and 12.88×10^{-3} Ω respectively. The discharge tube inductance = 50 nH at focusing time t = 4 μs.

A snow plough model is used to calculating the plasma sheath dynamics along the coaxial electrodes, for U_{ch} = 8 kV and pressure p = 1 Torr. These calculations demonstrated that the plasma sheath reached the muzzle end at the time of maximum discharge current and it had a maximum axial velocity≡3.1×10^6 cm/s at this position.

The experimental results of the axial distribution of the common visible radiation, I_{rad}, induced axial magnetic field induction, B_Z, azimuthal magnetic induction, B_θ, velocity of piston and luminous front velocity along the coaxial electrodes showed that, all the values mentioned above decayed from the breech up to the mid-distance between the breech and muzzle and after this, they increased with distance up to the muzzle for p= 0.5, 1 and 1.5 Torr and U_{ch} = 12 kV. At the muzzle, the ratio between the axial velocity of the luminous zone of plasma sheath and the axial plasma sheath (piston) velocity≡1.4×10^6 cm/s.

Generalized Gyrokinetics in Tokamaks

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Using canonical transformation, sets of novel guiding center variables are obtained. Generalized gyrokinetic equation for any frequency is developed for tokamak configuration, which is different from the ones obtained by Hitchcock and Hazeltine, Chen and Tsai, and Catto, Tang, and Baldwin. The formalism eliminates the limitation of the eikonal ansats. It is found that the shear of the radial electrical field affects the gyrofrequency. Ballooning representation is considered as a class of electromagnetic perturbations for general configuration in tokamaks.

Edge Plasma Behaviors in the HL-1M Tokamak

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Edge plasma parameters such as density, temperature and space potential have widely been measured by using Langmuir probes in HL-1M tokamak. Their distinct features in a few kinds of typical discharges were described. The improvement of particle confinement has been observed in the discharges with bias pumped limiter. Lower hybrid current drive can make particle confinement time not only increase a few times at lower density discharge ($\bar{n}_e < 1.0 \times 10^{13} \text{cm}^{-3}$) but also decrease about 50% in higher density one ($\bar{n}_e > 1.5 \times 10^{13} \text{cm}^{-3}$). The particle confinement time can suddenly increase in the plasma fuelled by pellet injection. It may increase about one order when the fuelling of molecule beam injection is used. The space potential barrier near the antenna appears on the discharges of ion cyclotron radio frequency during the first campaign, which forms a transport barrier.

3 mm Fast-scanning Microwave Heterodyne Radiometer for ECE Measurements on HT-7 Superconducting Tokamak

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A Fast-scanning ECE (FSECE) system was developed on HT-7 Superconducting Tokamak (R=122 cm, a=30 cm, $B_t \approx 1.5$~2.5 T), the system is designed for measuring Te profiles and for measuring superthermal ECE from a vertically viewing chord.

The Receiver of FSECE is a type of double-sideband frequency (DSB) heterodyne radiometer employing a very fast-scanning Backward-wave Oscillator

(BWO) as local oscillator (LO), a maximum of 16 frequency points in 78~118 GHz frequency range can be scanned in 0.65 ms period; video detector and amplifiers and data acquisition system have a frequency response of 500 kHz. The Measuring frequency positions of FSECE can be changed by program according to physics interests during experiments.

Both horizontal midplane view of plasma in low field side and vertically viewing antenna paths with polarization selection of O mode and X mode are installed. Radiometers are roughly calibrated on table by internal mounted noise generator, while relative calibration of radiometers at each frequency point was fulfilled by using of stable and repetitious ohmic plasmas with small variations of toroidal field to construct Te profiles; absolute calibration of temperature was made comparison against temperatures measured by Soft X ray Pulse Height Analyser (SXPHA) in the same discharges.

The FSECE system performance was testified under different experiments such as LHCD, LH heating, and ICRF heating and pellet injected plasma experiments.

References

[1] Efthimion P C, Taylor G, Ernst W, et al., Review of Scientific Instruments, 56, 949(1985).
[2] Hartfuss H J, Geist T, and Hirsch M, Plasma Physics and Controlled Fusion, 39,1693(1997).
[3] ZHANG Shouyin, Wan yuanxi, et al., Proceedings of Tenth Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Heating(EC10), the Netherlands, 1997, p.225.

Enhanced Confinement Regimes in HL-1M

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Improved confinement is one of the main topics in the tokamak experiment research. Several improved confinement regimes have been explored in the plasma biasing, LHCD and pellet injection experiments on the HL-1M tokamak. Here we concentrate the enhanced confinement regimes observed in HL-1M Ohmic discharges.

The first enhanced confinement regime is IOC mode. As the fuelling gas, fuelled with gas puffing and super-sonic molecular beam, is reduced during the current plateau phase it has been observed that the density is increased, indicating that the IOC mode is achieved, when the density $n_e<5\times10^{13}/cm^3$ and wall is siliconized but not fresh siliconized. In the IOC mode the central density is increased and the density profile is peaking compared with that in the normal Ohmic plasma, but the electron temperature and its profile is not changed in these two phases, similar to the observation on the ASDEX. It is also observed that the intensity in H_α radiation is decreased, indicating that the edge density is reduced, and the intensities of the soft X-ray radiation and plasma radiation are decreased, indicating that the central density is increased, which also is an indicator of the peaked density profile of the IOC plasma compared with the normal Ohmic plasma. From the electron density and temperature it can be derived that the central electron pressure p_e is enhanced and its profile is peaked, indicating that the confinement is enhanced. When $n_e > 5\times10^{13}/cm^3$, as the fuelling gas is same reduced the density is not apparently increased and the profile is almost not changed, indicating that the IOC mode can not be achieved beyond $n_e > 5\times10^{13}/cm^3$.

The second enhanced confinement regime is the sawtooth-free plasma. This sawtooth-free plasma can be achieved in hydrogen plasma, fueled with gas puffing, supper-sonic molecular beam injection and pellet injection, and in the density range of $n_e \leqslant 6\times10^{13}/cm^3$ with steadily and appropriate density increase combing with slow current ramp-up (dI_p/dt=0.5~1.0 MA/s) or secondary current ramp-up (dI_p/dt=0.5~2.5 MA/s) after wall silliconization but not fresh one. In this sawtooth-free plasma the central electron temperature is higher and the temperature profile is peaking than that in sawtoothing plasma, but the electron density and its profile is not changed. With the measured electron density and temperature the electron pressure $p_e(r)$ can be derived, from which it can be obtained that the central $p_e(0)$ is increased and the profile $p_e(r)$ is peaked in the sawtooth-free plasma compared with that in the sawtoothing plasma. The ion temperature in the sawtooth-free plasma is higher than that in the sawtoothing plasma. These observations indicate that the central confinement is enhanced in the sawtooth-free plasma compared with the sawtoothing plasma. Another very interesting thing is that the plasma radiation profile is peaking in the sawtooth-free plasma but hollow in the sawtoothing plasma, and the profile of the soft X-ray radiation is peaking too in the sawtooth-free plasma but flattening in the sawtoothing plasma.

The third enhanced confinement regime in HL-M is the negative current ramp plasma ($dI_p/dt \approx -2$ MA/s). In this plasma the global confinement time τ_E, the poloidal beta β_p are much increased and the internal inductance l_i is increased, indicating that the confinement enhancement is corresponding to the peaked current profile.

Particle and Heat Fluxes Induced by Electrostatic Fluctuations in the CHS Heliotron/Torsatron

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In the edge plasma region, particle and energy fluxes are induced by fluctuations of plasma parameters. In several tokamaks, the total particle flux due to electrostatic fluctuations is measured in the edge plasma region, by using Langmuir probes. In order to study the characteristics of edge plasma fluctuations and particle and energy transport induced by them in a helical device, a Langmuir probe array is installed on the CHS heliotron/Torsatron. The Langmuir probe array consists of 16 electrodes, and divided into 4 sets which are arranged radically with about 6 mm separation. Each set which consists of 4 electrodes works as a standard triple probe, where floating potentials at two positions separated by 4.5 mm in the poloidal direction are simultaneously measured. Fluctuations of poloidal electric field are estimated by the difference between these two signals of floating potential. Edge fluctuations were measured in NBI heated plasmas, where the magnetic axis position $R_{axis} \approx 92$ cm, the toroidal magnetic field $B_t \approx 1.4$ T, line-averaged electron density $n_e \approx 1.5$ (10^{19} m^{-3}), and the central electron temperature $T_e \approx 0.5$ keV. In the plasmas, edge plasma parameters were measured with the Langmuir probe array. The electron temperature and density near the edge ($r/a \approx 0.9$ to 1.0) are varied from 25 to 10 eV and from 0.4 to 0.1 (10^{19} m^{-3}), respectively. The radial particle flux induced by electrostatic fluctuations is derived by $\langle E_{pol,1}\, n_{e,1} \rangle / B_t$, where $E_{pol,1}$ and $n_{e,1}$ are fluctuations of poloidal electric field and electron density, and $\langle\ \rangle$ denotes an ensemble average. Significant results are that the particle flux around $r/a \approx 0.94$ is inward, and in the other radial positions, it is outward. The total particle flux induced by electrostatic fluctuations on $r/a \approx 0.92$ and 0.98 are about 4.5 and 2.5 (10^{19} m$^{-2} \cdot$ s^{-1}), respectively. In the inner position, higher frequency components of fluctuations ($50 < f < 80$ kHz) contribute to the total flux. The contribution of lower frequency components ($f < 20$ kHz) is dominant in the outer position. Fluctuation induced heat flux also exhibits the similar reversal in the particular radial position. Correlation between the flux reversal and electron density, heating power and the magnetic axis position is under investigation.

Excitation Experiments of Alfvén Eigenmodes by AC Current Flowing Along the Magnetic Field Line in CHS

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Energetic particles such as alpha particles and fast ions could destabilize Alfvén eigenmodes (AEs) in a fusion reactor. If these modes become unstable, the loss of particles is enhanced and consequently prevents ignition. AEs destabilized by NBI- or RF-produced energetic ions were identified in several tokamaks and helical systems. In the heliotron / torsatron device CHS, the toroidicity-induced Alfvén eigenmodes (TAEs), driven by energetic ions created by NBI, were observed for the first time. In order to know the stability of energetic-ion-driven AEs, it is required to evaluate the damping rate of AEs without energetic ion drive. For this reason, we installed four loop antennas around every 90-degree for direct excitation of AEs in CHS. These antennas are used in two ways: one is as usual four external loop antennas and the other two pairs of electrodes. In the experiment the latter method was adopted. All antennas as an electrode were inserted into the plasma edge $r/\langle a \rangle \approx 0.9$, to induce AC current flowing along the magnetic field line of CHS. This method can induce small magnetic perturbations ($\delta B/B \approx 10^{-5}$) to the plasma and could excite AEs. Excitation experiment of AEs was carried out in an after- glow of NBI heated plasma, so that the drive of AEs by energetic ions would be suppressed and only external AC current contributes to excite AEs. In the after-glow phase, the electron density is monotonously decreased. Magnetic fluctuations shows a resonance like peak during the density decay phase, where the frequency of the electrode current is kept constant. The peak is shifted toward the lower density phase in the after-glow, with increase in the excitation frequency. The frequency is inversely proportional to the square root of the electron density. It is thought that these magnetic fluctuations are to be Alfvénic waves. When magnetic fluctuations with odd mode structure are applied, around the fluctuation peak magnetic fluctuations with n=1 structure start to propagate in the opposite direction of the toroidal magnetic field, while except the phase fluctuations exhibit the $|n|$=1 standing wave. Note that the excitation frequency is lower than the TAE gap frequency but agrees well with m/n=3/1 GAE frequency in the plasma center. This experiment suggests that AC current induced by the electrodes near the edge can excite AEs directly in toroidal plasma.

Characteristic Features of Sawtooth Crash in CHS

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In many tokamaks, sawtooth oscillations are commonly observed. When the safety factor q in the plasma center goes down to less than unity, the temperature and density inside the q=1 surface suddenly drop after sawtooth crash. This is called the "core crash". In negative magnetic shear configuration in TFTR, another kind of sawtooth crash was observed. Fluctuations with $m=2/n=1$ mode structure appear at the sawtooth event and the central electron temperature and density do not immediately drop. This type of sawtooth crash is called the "annular crash". We report characteristic features of sawtooth crash observed in the CHS heliotron/torsatron, where the rotational transform profile is similar to that in negative magnetic shear configuration in a tokamak. In neutral beam heated plasmas, sawtooth oscillations are observed in soft X-ray signals which are measured using 20 channel PIN photodiode soft X-ray (SX) detector array with a pinhole covered by Be foil (8 μm in thickness) and also in line integrated electron density measured by HCN interferometer, where the toroidal magnetic field is about 0.9~1.5 T, line averaged electron density is about $2{\sim}3\times10^{19}$ m^{-3} and neutral beam driven plasma current is about 10 kA. The sawtooth crash is accompanied by the $m=2/n=1$ burst like magnetic fluctuations. The SX intensities around $r/a\approx0.5$ near the $1/q=1/2$ rational surface just after the crash drop suddenly, but the intensity at the plasma center does not immediately drop. This indicates a character of the annular crash. On the other hand, the relative change in line integrated electron density is less than 5 % and much smaller than that of SX signal ($\approx$30%). Relative change in the SX intensity is caused by several contributions: relative changes in electron temperature, electron density and impurity content. In this experimental condition, it is thought that the relative change in the SX intensity is dominated by the electron temperature change. Conditions that the annular crash is induced are under investigation.

CN0101735

Study of the Ohmic Plasma Density Limit in HL-1M

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In order to achieve thermonuclear burn, future fusion experiments must safely operate at rather high density. Present experiments, however, show that the useful tokamak operation space is limited toward high density by various processes. So understanding of the physics of the density limit is of particular importance for the design and operation of future reactor device.

This paper presents L-mode density behavior in HL-1M tokamak, and studies systematically the influence of varied discharge parameter at ohmic plasma density limit. In the machine HL-1M, there are many physical processes limiting the attainable density, which including: fuelling isotope effect (deuterium, hydrogen), fuelling methods (gas puffing, pellet injection and supersonic molecular beam injection), and condition of vacuum wall coating (boronization and siliconization). The maximum density ($\bar{n}_e = 8\times10^{19}\,m^{-3}$) has been obtained with supersonic molecular beam injection fuelling, it was about 80% Greenwald density limit. The sequence of processes leading to a density limit disruption was experimentally analyzed in detail for ohmically heated plasma. During the density increase in the SMB injection phase, the high edge plasma radiation on the high field side were observed, then the MHD-instabilities lead to a plasma disruption. Experiments result show that this density limit may be caused by an unfavourable balance between input and radiated power, and the Murakami parameter is a good scaling parameter for the density limit of HL-1M discharge.

During the deuterium and hydrogen discharges, the density limit results show that there is an isotope effect in the density limit. Under the same operation condition. the density limit in deuterium is some higher than in hydrogen plasmas, and the scaling is about $\bar{n}_e \propto m^{1/3}$.

In HL-1M, the fuelling methods of gas puffing, pellet injection and supersonic molecular beam injection have performed. The density limit directs proportional to the density peaking factor.

Different wall conditioning procedures have been applied during limit discharge. Experiment indicated the density limit dependent on the purity of the plasma.

Features of the Electron Energy Balance in High Density Ohmic H-Mode in TUMAN-3M Tokamak

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An Internal Transport Barrier (ITB) was found in high density ohmically heated H-mode plasma in the TUMAN-3M[1]. Typical plasma parameters in the shots with ITB were as follows: R_0=0.53 m, a_l=0.23 m, B_t=0.7 T, I_p=140 kA, $T_e(0)$=500 eV, $T_i(0)$=180 eV, $\bar{n}$=(1.5≒5)×10^{19} m^{-3}. In the experiments on TUMAN-3M tokamak the ITB was observed in ohmically heated plasma with monotonic q-profile. The ITB revealed itself as a formation of a steep gradient on electron temperature and density radial profiles measured by Thomson scattering and by interferometry. As a result of the transport suppression the plasma density increased dramatically from 1.5×10^{19} to (4~5)×10^{19} m^{-3}. The increase in the density was accompanied by some decrease in the central electron temperature. At high density the electron-ion equipartition time decreases substantially. As a result the power transfer from electrons to ions may become an essential part of the electron heat losses. Transport analysis was performed in order to study the evolution of the electron heat balance through the ITB formation, to clarify the reason for $T_e(0)$ reduction in the conditions of increasing density and to analyze a role of transient phenomena in the ITB formation. The results of the transport simulations are presented in this paper.

References

[1] Lebedev S.V., Andreiko M.V., Askinazi L.G., et al, 1998 ICPP & 25th EPS Conf. on Control. Fusion and Plas. Phys., ECA, Vol.22C, 1998, pp. 313-316.

Upper Hybrid Resonance RADAR Scattering Diagnostics of Small Scale Turbulence in FT-1 Tokamak

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The new diagnostic technique, utilizing RADAR microwave scattering in the Upper Hybrid Resonance (UHR) has been developed and applied for study of spontaneous magnetic field and density turbulence in the FT-1 tokamak. Such merits of UHR scheme as 1D probing geometry, enhancement of cross section and fine localization of scattering region are completed in the diagnostics by wave number resolution provided by scattered signal time delay measurements. The experiment was performed at the FT-1 tokamak (R=62.5 cm, a=15 cm, B_t=1 T, I_p=30 kA, $n_e(0)=10^{13}$ cm^{-3}). The probing extraordinary wave at frequency 27.6 GHz, power 50W was launched into the plasma from high magnetic field side of the torus. A short (7 ns) pulse amplitude modulation of the incident wave was used with repetition time of 70 ns. The gate modulation technique was utilized for the scattered signal time delay measurements.

The small scale component of magnetic turbulence was studied using the effect of Cross Polarization Scattering (CPS) in the UHR. The CPS ordinary wave was measured at the low magnetic field side with the time delay up to 20 ns, which corresponds to the fluctuation wave length of 0.04 cm. The magnetic field turbulence wave number and frequency spectra are estimated from experimental data.

The small scale density turbulence was studied using the signal, Back Scattered (BS) in the UHR. The maximum signal was measured there for time delay of 10 ns, which corresponds to the cross section maximum at wave number 100 cm^{-1}. The experimental results are consistent with usually observed fluctuation wave number spectrum decreasing as q^{-3}. Both the CPS and BS frequency spectra width are shown to increase linearly with the measurements time delay and correspondingly with the fluctuation wave number, however the BS spectra are a factor of 4 wider. The explanation for these effects is proposed, based on the ray tracing calculations, predicting growth of poloidal wave number for the probing wave in the UHR.

CN0101738

Feedback Control of Plasma Current and Horizontal Position in HT-7 Tokamak

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There is a strong magnetic coupling between poloidal field coils of superconductive tokamak HT-7, These coils are connected to individual power supply. The control system for the plasma current and horizontal position control has been designed and showed satisfactory results with feedback control of multivariable feedforward decoupling and var-parameter PID controller to simultaneously modulate power supplies. The outline of the control system is presented.

The Runaway Generation and Disruptive Instability in the ISTTOK Tokamak

CN0101739

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The runaway generation is one of the fundamental physical processes in plasmas being under the action of external electric fields. This phenomenon has been intensively studied both experimentally and theoretically. However, the investigations of runaways and their role in future devices are still actual, because the appearance of runaways in disruptions or under conditions of fast current ramp-down in reactor-scale tokamaks will lead to unacceptable electromechanical and thermal stresses. Moreover, the presence of runaways can induce several deteriorative instabilities in toroidal plasmas.

Typically, the runaway process develops in the low collisional plasmas with relatively high plasma current. Usual plasma discharges in the ISTTOK tokamak (major radius $R_0 = 0.46$ m, average plasma radius $\langle a_{pl} \rangle \leqslant 0.085$ m, toroidal magnetic field $B_0 \leqslant 0.5$ T) are characterized by relatively high values of plasma current density

$\langle j_{pl} \rangle \cong 0.2\sim0.4$ MA/m^2 at the plasma density range $(2\sim6)\times10^{18}$ m^{-3}.

This paper presents experimental results on the detection of runaways in the ISTTOK discharges. A conventional criterion of runaway generation inferred from the theory of runaways was applied to the experimental data for a certain number of discharges. This criterion was satisfied for a large amount of data indicating the presence of runaways. The calculated values of the runaway particle flux rate are high enough in order to enable the diffusion of 10%~20% of all plasma electrons into the runaway regime.

It is shown that due to the presence of a runaway fraction in the plasma current the characteristic times of current decay are significantly higher than those deduced from the analysis of conventional resistive and inductive features of the plasma column in ISTTOK. The influence of large damping time due to presence of runaways on the performance of alternate plasma current discharges without dwell-time in ISTTOK is estimated.

The runaways were also detected in kind of typical relaxation oscillations in discharges with partial disruptive activity, where the runaway generation has been linked to the distortion of the discharge equilibrium and stability.

Plasma Coaxial Discharge for Thin Film Deposition

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A coaxial discharge, of 6 capacitors each with 7.71 μF, is used to explore plasma thin film coating by insert a graphite powder at the breach of the coaxial head. Plasma current sheath reached 25 kA, after 10 μs from the start of the discharge. The plasma current sheath velocity was 10^4 cm/μs. The plasma carrying the ion particles of carbon reach the substrate with temperature and density of 7 eV and 10^{13} cm^{-3} respectively. The thin film deposited on the glass substrate has some homogenous structure for about 4 cm diameter while the st-st electrode material appeared after that. Several types of the deposited thin film material are shown for different operating condition. The rate of deposition per discharge pulse is presented. It was concluded that the design of the system can be used for deposition, but it has to be changed to obtain phase change of carbon.

CN0101741

Miniature Coaxial Plasma Injector for Diagnostics by Beam Plasma Interaction

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A miniature coaxial gun has been used to study the interaction between plasma beam and low density plasma formed in glow discharge. The peak discharge current flow between the coaxial electrodes was 5.25 kA as a single pulse with pulse width of 60μs. Investigations are carried out with argon gas at pressure 0.4 torr (1 torr = 133. 3224 Pa). The plasma stream ejected from the coaxial discharge propagates in the neutral argon atoms with mean velocity of 1.2×10^5 cm/s. The plasma stream temperature and density were 4.2 eV and 2.4×10^{13} cm^{-3} respectively. An argon negative glow has been used as base plasma where its electron temperature and density were 2.2 eV and 6.2×10^7 cm^{-3} respectively. When the plasma stream propagates through the negative glow discharge region its velocity decreased to 8.8 $\times$ 10 cm/s, and also the plasma electron temperature decreased to 3.1 eV, while the stream density remained the same. An excited wave appeared on the electric probe signals which is typically the plasma frequency of the plasma under consideration. Simulation of the problem showed that this method can be applied for diagnostics within the region of investigation. Further studies for high temperature, dense and magnetized plasma will be considered.

CN0101742

An Analytical Analysis of Relaxation States in Toroidal Plasma with a Coaxial Helicity Injection

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The Euler-Lagrange equations are derived from the principle of minimum dissipation to represent the relaxation state in toroidal plasma with a coaxial helicity injection. An analytical analysis is presented to give the solution of the toroidal density. The solution is the sum of three convergent infinite series, the results are in

good agreement with those derived through numerical method as well as the experimental results. The sensitivity of solution to the boundary condition is discussed in the final section.

CN0101743

Scaling of Electron Kinetic Energy Confinement for Ohmic Discharges in HL-1M

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A database of the electron energy confinement for ohmic heating plasma in HL-1M has been compiled with aid of the calculating electron kinetic stored energy. The electron energy confinement in the database is examined with the existing ohmic energy confinement scaling law. It is shown that the τ_E^e of HL-1M fits to the Alcator scaling of ohmic discharges and the density which transit the density scaling from linear to saturated is about $4.8\times10^{13}\mathrm{cm}^{-3}$. The result of statistical regression shows that the scaling law of electron energy confinement time in HL-1M is: $\tau_E^{\text{e-regression}} = 2.058\bar{n}_e^{0.78\pm0.02}T_{e0}^{0.79\pm0.04}q_a^{0.39\pm0.06}$. Finally the relation between the scaling and energy transport are discussed.

CN0101744

CCD Photography of Pellet Ablation in HL-1M Tokamak

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This paper describes experiment results of Ha radiation photos using CCD camera in HL-1M tokamak in 1998. The observation is performed from the direction of injection. The CCD camera parameters, experimental setup and positioning are described. The photos of various ablation cloud, pellet speed and trajectory are obtained. The spatial profile of the radiation is given by treating photo. The track bending and the appearance of striation are analyzed, inquiring into the physical mechanism of pellet-plasma interactions. Therefore this work lays the foundation of further measurement for local magnetic field and current profile of plasma with CCD camera under the condition of pellet injection.

The Research Evolution of Reversed Field Pinch Plasmas on SWIP-RFP Device*

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The reversed field pinch (RFP) plasma is one of the most actively studied alternatives at present. SWIP-RFP (Major radius R/minor radius a=0.48 m/0.1 m, R/a=0.48 m/0.09 m with molybdenum limiters) was a small dimension RFP device in Southwestern Institute of Physics (SWIP). It was put into operation in 1991 and shut down in 1998. The typical discharge parameters obtained for RFP and Ultra Low safety factor q(ULQ) configurations were: plasma duration≈0.9 ms (≈1.2 ms for ULQ), plasma temperature $T_i \approx T_e \approx 80$ eV, RFP sustainment time≈0.4 ms, global energy confinement time $\tau_E \approx 0.03$ ms and peak plasma current $I_p \approx 80$ kA(≈100 kA for ULQ). Because there was no effective apparatus for plasma pre-ionization, a capacitor bank was used to activate a negative pulse of I_p just before the positive pulse of I_p for physical research. The ULQ confinement was studied with the toroidal field control, we found that the ULQ plasmas were stable with different edge q values. Because the plasma temperature was low, the RFP sustainment time was limited during relaxation process. The plasma sustainment time was twice as long as the RFP sustainment time. Many wall-conditioning methods were used. Evident fluctuations were detected on the waveform of the edge toroidal field. To achieve more stable RFP confinement, a high plasma toroidal voltage V_ϕ was required. Large V_ϕ drove large I_p and resulted in very large plasma pinch factor Θ (maximum value about 2.5). From the viewpoint of plasma relaxation, higher Θ accompanies larger magnetic helicity loss. Then the reduction for V_ϕ on SWIP-RFP was important for RFP confinement improvement. The time evolutions of plasma relaxation parameters such as the original helicity K (= $\int A \cdot B \mathrm{d}V$, where B is the field, A the vector potential), the total helicity K_{totol} (=$K-\Phi\Psi$, where Φ is the toroidal field flux, Ψ the poloidal field flux through the major torus) and the magnetic energy U_m have been calculated. The results showed that though K and U_m increased, K_{total} decreased. The calculation results indicated that these parameters did not meet the relaxation theory requirements. The increases of K and U_m were caused by the enhancement of the poloidal field produced by large I_p. So, if we wanted to conserve K_{total}, V_ϕ had to be decreased (as $\Psi = \int_0 V_\phi dt$). Above results indicated that the device required modifications for V_ϕ reduction. But it is difficult to do this because V_ϕ relates with many factors such as energy confinement, plasma temperature, plasma pre-ionization, plasma equilibrium, magnetic symmetry, vacuum chamber structure, etc. Because SWIP-RFP was a small device, it was difficult to choice between modifying it and stopping operation. We finally chose the later. But the further studies on RFP theory and experimental data are going on.

CN0101746

Two-Dimension Investigation of HL-2A Tokmak Divertor Plasma

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Recently, attention has been drawn to the particle and energy transport of the divertor plasma and Scrape-off Layer plasma in TOKAMAK. The crucial tasks faced by the divertor can be divided into four main aspects:

1. Exhausting plasma power from main plasma;
2. Removing fuel and helium ash from system;
3. Eliminating and reducing impurity production;
4. Screening impurity.

In addition, all of these must be sufficiently performed while maintaining good core confinement a relatively high plasma density to enhance fusion reactivity.

This paper studies the transport of particle and energy of Scrape-Off layer and plasma. The two dimensional (2-D) model combines particle in code EDG2D which simulates Coulomb collision and charged/neutral interactions (charge exchange and electron impact ionization). HL-2A divertor is taken as an example of divertor configuration. The results are compared with other SOL transport models.

Preliminary Results from the TCABR Tokamak

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After a long period of assembling and repairing faulty components, tokamak discharges started this year to be routinely obtained in TCABR. TCABR was brought from Lausanne - Switzerland some years ago. It is a middle size ohmic heating tokamak with rectangular cross section vacuum chamber; however, initially, it will be running with circular cross section plasmas. The machine nominal parameters are: Major Radius: R_0 = 0.61 m; Minor Radius: a = 0.18 m;Plasma Current: I_P=120 kA; Discharge Duration: τ_d=100 ms; Central Electron Temperature: T_e=500 eV; Maximum Average Electron Density: n_e=6$\times$10^{19} m^{-3}; Toroidal Magnetic Field: B_T=1.0 T; Currently, the ohmic heating system is operating at a maximum of 3.5 kV voltage level, bellow the maximum design of 6 kV. Discharges with a maximum plasma current of I_p=90 kA have been obtained for pulse lengths of $\tau_d \leqslant$ 100 ms. During the first period of operation, mainly low-pressure discharges were obtained, characterized by typical run-away conditions. More recently high-pressure and resistive discharges could be obtained more routinely. The main scientific goal planned for this machine is the investigation of Alvén heating and transport control using a newly designed wave excitation system. To diagnose the plasma, a new system of internal coils, for optimized equilibrium determination and a set of Mirnov coils are installed. Three-channel microwave interferometer and an optical spectrometer are under commissioning. Also, the bolometric, soft X-ray and visible interferometer system are being installed. The data acquisition system, based upon new VME modules, is already operational.

Recent Results from University of Washington Helicity Injection Current Drive Program

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The Helicity Injected Torus-II (HIT-II) spherical torus is capable of both Coaxial Helicity Injection (CHI) and transformer action current drive. HIT-II has a major radius of 0.3 m, a minor radius of 0.2 m, an aspect ratio of 1.5 m, with an on axis magnetic field of up to 0.67 T. HIT-II provides equilibrium control, CHI flux boundary conditions, and transformer action using 28 poloidal field coils, using active flux feedback control. HIT-II has driven up to 200 kA of plasma current, using either CHI or transformer drive. Combinations of both CHI and transformer have been successfully performed. Internal reconnection events (IREs) are typically observed during transformer operation. Initial results suggest their appearance or non-appearance may be controlled by changes in the loop voltage and/or application of voltage to the CHI electrodes. Bulk plasma ion flow has been measured using a high resolution Doppler broadening spectrometer. CHI operation with the central column as an anode (which operated as a cathode in all previous experiments) has been performed. An overview and recent results of the HIprogram will be presented.

The Protosphera Experiment and the PROTO-PINCH Testbench

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Spherical Tori $A=R/a<2$ were originally proposed by M. Peng and his collaborators at ORNL[1]. They are based on economical (low aspect ratio=low volume=low cost) and physical (probable no disruptions, low geodesic curvature, high beta) attractive features. These features have been confirmed by the START[2] experiment at Culham.

The decrease in the aspect ratio and the trend to the Ultra Low Aspect Ratio Torus (ULART, $A<1.3$) is a necessary further step in Spherical Tori. The main problem of a Spherical Torus Reactor is the impossibility of shielding the central rod from the neutron flux, therefore the central rod cannot be superconducting. The PROTO-SPHERA experiment (Spherical Plasma for HElicity Relaxation Assessment), which will be built at Frascati, will be devoted to demonstrate the feasibility of an ULART where a stabilized screw pinch takes the role of the central rod. Two polar cap electrodes will feed the central screw pinch and sustain the ULART by driving poloidal field by DC Helicity Injection. The TS-3[3] ULART experiment (Tokyo University) has successfully obtained a similar magnetic configuration. Thus the main goal of PROTO-SPHERA will be to show that efficient helicity injection maintains a stable configuration; the problem of damages to the central rod is however turned to the problem of avoiding damages to the electrodes.

A benchmark for the electrodes is required because the high value of power handled by them. The electrodes' benchmark PROTO-PINCH has been built and operated. It has produced a screw pinch with roughly the same geometrical dimensions of the screw pinch of PROTO-SPHERA, with a simpler mechanical configuration of the electrodes. PROTO-PINCH, with an anode-cathode distance of 0.75 m and a stabilizing magnetic field B=1.5 kG, has a current capability of $I_{\rm Pinch}$=1 kA, (with $q_{\rm Pinch}\geqslant 2$). The technical solution for the 5 cm diameter electrodes are: (i) a stainless steel hollow anode, with H_2 puffed through it (a feed-back system stabilizes the pressure $p_{\rm H}$ in the vessel); (ii) a directly heated Thoriated Tungsten hollow cathode (6 spirals of W-Th) built by refractory metals (Mo and Ta) and insulators. The cathode can be heated up to 2300 K, by a total current $I_{\rm cath}$=230 A. Self-sustained pinch discharges have been obtained with B=0.8 kG, $I_{\rm Pinch}$=250 A (limit of present power supply) and $V_{\rm Pinch}$=50 V. The pinch current has been obtained in filling pressure range $p_{\rm H} = 1\cdot 10^{-3}\sim 1\cdot 10^{-2}$ mbar.

References

[1] Y-K. M. Peng and D.J. Strickler, Nucl. Fus. 26 (1986) 1139

[2] A. Sykes, R. Akers, L. Appel, et al., Plasma Phys. Control. Fusion 39 (1997) B247

[3] N. Amemiya, A. Morita, M. Katsurai, JPSJ 63 (1993) 1552

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