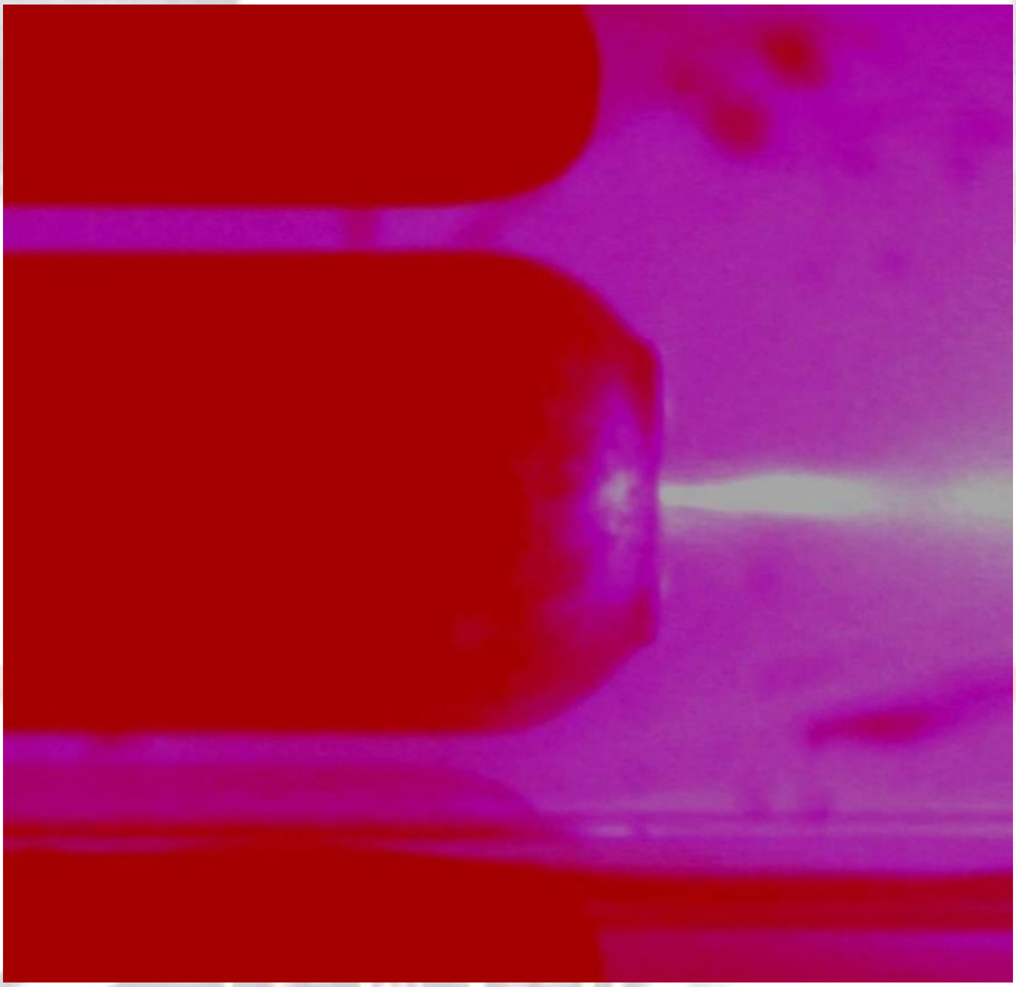
International Symposium on Plasma Focus

in series SPFE 2013

Friday 14 June 2013

Nilai Springs Resort Hotel, Nilai, Negeri Sembilan, Malaysia



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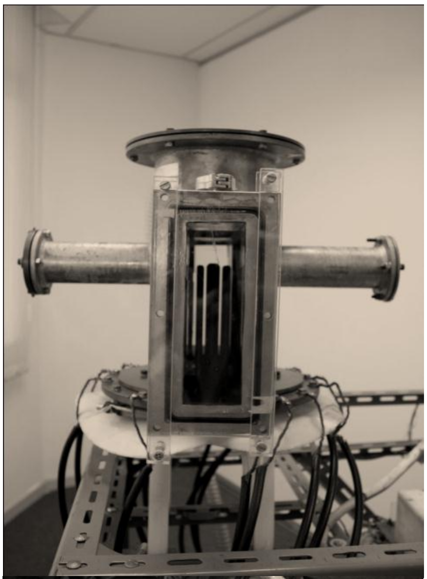

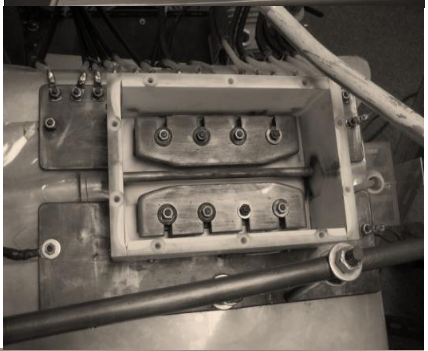

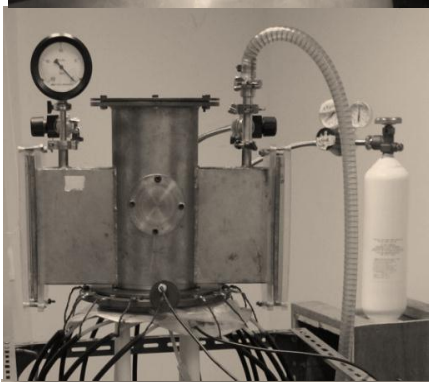

Introduction

The **International Symposium on Plasma Focus in series SPFE 2013 will be held on Friday 14 June 2013 at Nilai Springs Resort Hotel following the IAEA 2nd RCM for the CRP on Investigations on Materials under High Repetition and Intense Fusion Pulses, 10 - 13 June 2013.**

The Symposium aims to share research work of the CRP members. It will be addressing Plasma Focus Research and should serve as a platform for exchange between scientists particularly in Malaysia and its neighbouring countries.

The series SPFE 2013 is an annual one-day seminar for plasma focus scientists to share their current thoughts, research projects and results. The seminar is supported by AAAPT, IPFS, NIE-NTU, UTM and INTI IU. The first SPFE was held in August 2010.

The Centre for Plasma Research at INTI International University was conceived in November 2007 with the hosting of the Universal Plasma Focus Laboratory Facility. Since then the UPFLF Lee Model code has received wider international adoption in assisting design and interpretation of plasma focus experiments.

In December 2008, a gift of the 3kJ Plasma Focus from NIE-NTU Singapore to INTI IU allows the synergy of experiments and numerical experiments here at the Centre for Plasma Research in INTI IU.

Advisor: Prof Dr Lee Sing

Organizing Committee

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Time	Programme
8.15 am – 8.50 am	Breakfast and Registration
8.50 am – 9.20 am	Welcome Address Opening Speeches Dr Richard Kamendje, Representatives of IAEA Prof Dato' Dr Ibrahim Ahmad Bajunid, Deputy Vice Chancellor INTI IU
9.20 am – 9.30 am	Group Photo
9.30 am – 10.00 am	Invited Paper 1: Professor Vladimir Gribkov *Experiments provided with Dense Plasma Focus device in the field of the Nanosecond Impulse Neutron Investigation System (NINIS) on disclosure of explosive and fissile materials*
10.00 am – 10.30 am	Invited Paper 2: Professor Pavel Kubes *Influence of the anode material and external magnetic field of the transformation of the plasma and neutron production in plasma focus discharge*
10.30 am – 11.00 am	Invited Paper 3: Professor Sor Heoh Saw *Deuteron Beam Properties for Plasma Focus Devices*
11.00 am – 11.15 am	Tea break
11.15 am – 11.45 am	Invited Paper 4: Professor Igor Garkusha *Dynamics of dense magnetized plasma in pinching discharge of magnetoplasma compressor*
11.45 am – 12.15 pm	Invited Paper 5: Assoc Professor Rajdeep S Rawat *Plasma Focus: Uniqueness, Universality, Scalability and Possibilities*
12.15 pm – 12.45 pm	Invited Paper 6: Dr Sergey Latyshev, *Numerical Simulation of the Thermal Effects in Plasma Focus Experiments*
12.45 pm – 1.45 pm	Lunch
1.45 pm – 2.15 pm	Poster Session
2.15 pm – 2.45 pm	Invited Paper7: Professor Alexander Voronin *Plasma jet for material irradiation and fuelling the tokamak*
2.45 pm – 3.15 pm	Invited Paper 8: Dr Leopoldo Soto *Characterization of Plasma Bursts from a Hundreds of Joules Plasma Focus and its Applications to Study the Effects of Si and W Targets*
3.15 pm – 3.45 pm	Invited Paper 9: Dr. Marius Wirtz *Thermal fatigue and thermal shock response of plasma facing materials and components*

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Time	Programme
3.45 pm – 4.15 pm	Invited Paper 10: Dr H R Yousefi *TiN and Ti-Cu-N Coated Stainless Steel by Using a low energy Plasma Focus Device*
4.15 pm – 4.30pm	Tea break
4.30 pm – 5.00 pm	Invited Paper 11: Professor Leopoldo Soto *Advances in the Program of Plasma Focus Scaling Research and Miniaturization of Plasma Focus Devices*
5.00 pm – 5.30 pm	Invited Paper 12: Dr Satish C. Gupta *Fusion of 3He with 3He inside a medium energy plasma focus device*
5.30 pm – 6.00 pm	Invited Paper 13: Professor Jalil Ali, *Radiative Cooling and Collapse-Comparative study of a range of gases*
6.00 pm – 6.30 pm	Invited Paper 14: Professor Sing Lee *Plasma Focus Ion Beam Properties- for various gases*
7.00 pm - 9.00 pm	Closing and Dinner

Experiments Provided with Dense Plasma Focus Device in the Field of the Nanosecond Impulse Neutron Investigation System (NINIS) on Disclosure of Explosive and Fissile Materials

V.A. Gribkov

A.A. Baikov Institute of Metallurgy and Material Sciences, Russian Academy of Sciences, Moscow 119991, Leninsky prospect 49, Russian Federation, gribkovv@yahoo.com

Abstract

The lecture presents a survey of the experimental results obtained with Dense Plasma Foci working both with pure deuterium and deuterium-tritium mixture during last several years in the field of a single-shot interrogation system. This system is designed for unveiling of hidden items contained possibly explosives and fissile materials. We use elastic and inelastic neutron scattering as an instrument for the examination of suspicious items. Importance for these purposes of compact DPF chambers and screened movable boxes with detectors and oscilloscopes highly protected from harsh environment is specially discussed. Methods of data acquisition and processing needed for the effective system use will be enlightened. This system may have a niche among the numerous methods of interrogation of shady items. In particular it has to be useful for examination of fast-moving objects like cars, train carriage, etc. and for unveiling of objects containing fissile materials.

Influence of the Anode Material and External Magnetic Field of the Transformation of the Plasma and Neutron Production in Plasma Focus Discharge

P Kubes[1], M Paduch[2], J Cikhardt[1], D Klir[1], J Kravarik[1], K Rezac[1], J Kortanek[1], M Scholz[3], E Zielinska[2], L Karpinski[4]

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[3]*Institute of Nuclear Physics, Krakow, Poland*
[4]*Rzeszow University of Technology, Rzeszow, Poland*

Abstract

In this paper, the influence of the anode material and external magnetic field on the dynamics of the pinch and neutron production is presented following from the results of the temporally resolved measurements using X-ray, interferometry and neutron diagnostics performed on the plasma focus PF-1000 device with deuterium as the filling gas at the current of 2 MA and neutron yield above 10^{10}. The axial center of the anode face was constructed from a tungsten circuit plate. During the first hard X-ray and neutron pulse, 4×10^{17}–10^{18} of the ions were evaporated from the anode and were transported into the plasma column. A description is provided of their influence on the soft X-ray emission, decrease of the velocity of the plasma column transformation, decrease of the total neutron yield to 40% and decrease of the energy of individual deuterons producing neutrons. The permanent magnets with magnetic field a few hundredths of tesla were used as inside the anode body as in front of the end of the dense column. This magnetic field depresses the implosion velocity, decreases the neutron yield to 50%, stabilizes the pinch column, increases its axial symmetry and depresses the velocity of transformations of internal structures. These consequences enabled the description of the evolution of the internal structures in the dense column in more detail by the transformations of the poloidal and toroidal magnetic fields inside the plasma structures.

Deuteron Beam Properties for Plasma Focus Devices

S H Saw

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Abstract

Within the context of the International Atomic Energy Agency (IAEA) Coordinated Research Program (CRP) "Investigations of Materials under High Repetition and Intense Fusion-Relevant Pulses" is defined an area "Investigation of Fusion-relevant Pulses from Plasma Focus Devices- Scaling and Properties". Our work in this area has focused on the properties of deuteron beams of plasma focus devices of the CRP partners. Our survey on the subject showed that measurements on plasma focus ion beams include various advanced techniques producing a variety of data, typically using inconsistent even misleading units and with no attempt to correlate results among machines and experiments. The overall picture is confused and the sum total of research had produced neither discenable scaling trends nor benchmark numbers. This present paper uses the Lee Model code [S Lee, http://www.plasmafocus.net (2012)], integrated with experimental measurements to provide the basis for reference numbers and the scaling of deuteron beams versus stored energy E_0. The ion number fluence (ions m^{-2}) and energy fluence (J m^{-2}) computed as 2.4-7.8x10^{20} and 2.2-33x10^{6} respectively are found to be independent of E_0 from 0.4 – 486 kJ. Typical inductance machines (33-55 nH) produce 1.2-2 x 10^{15} ions per kJ carrying 1.3-4 % E_0 at mean ion energy 50-205 keV; dropping to 0.6x10^{15} ions per kJ carrying 0.7 % E_0 for the high inductance INTI PF.

Dynamics of Dense Magnetized Plasma in Pinching Discharge of Magnetoplasma Compressor

I.E. Garkusha[1,2], T.N. Cherednychenko[1], M.S. Ladygina[1], V.A. Makhlay[1], Yu.V. Petrov[1], D.G. Solyakov[1], V.V. Staltsov[1], D.V. Yelisyeyev[1]

[1]*Institute of Plasma Physics of the NSC KIPT, 61108 Kharkov, Ukraine*
[2] *V.N. Karazin Kharkov National University, Kharkov, Ukraine*

Abstract

Dense compressive plasma streams produced by magnetoplasma compressors (MPCs) are considered now as prospective and efficient source of EUV radiation from magnetized plasma to be used for different technological applications. In this report the dynamics of pinching discharge in MPC device operating with different gases is analyzed. In performed experiments an additional injection of xenon (as radiative admix) is organized into the compression zone directly, while the plasma pinch was created in MPC discharge using gases of various mass (helium, argon etc.). Application of different gases allowed investigations of the mass flow rate influence in MPC discharge on the plasma compression and heating. In particular, for different atomic mass of working gas, similar mass flow rate could be provided by adjustment of the residual gas pressure. It is demonstrated experimentally, that with reduction of the initial pressure of the background gas in the chamber, the maximum density and plasma temperature in the compression zone are grown. The intensity of radiation in EUV wave-range is increased with decreasing initial density. It can be realized by maintaining the mass flow rate for used heavier gases. In this case, the radiation intensity increases considerably. Radial distributions of energy density in plasma streams for different MPC modes of operations, spatial distributions of electric current and spatial distribution of electromagnetic force in plasma stream are investigated. Total energy contained in the plasma stream strongly depends on the discharge current, mass flow rate and sort of working gas. Energy transfer efficiency from the discharge to the plasma stream is discussed.

Plasma Focus: Uniqueness, Universality, Scalability and Possibilities

Rajdeep Singh Rawat

Natural Sciences and Science Education, National Institute of Education, NTU, Singapore 637616

Abstract

The plasma focus device is an alternative magnetic fusion device where a fast capacitor bank is discharged through the coaxial electrode assembly generating a supersonic plasma whose dynamics is essentially controlled by very high pulsed discharge current. The short-lived plasma is electromagnetically compressed in hot and dense pinch plasma column on ns time scale with generation of multiple radiations such as EUV, soft and hard x-rays, relativistic electrons, high energy ions and even fusion neutrons (if operated with deuterium). The device is very unique in the sense that it exhibit universality in gross plasma dynamics and plasma parameters but at the same time provide up- or down- scaling of the yields of multiple radiations of interest. The multiple radiations from this device also open up vast range of possible applications of this device which will be discussed in the meeting.

Numerical Simulation of the Thermal Effects in Plasma Focus Experiments

S.V.Latyshev, V.A. Gribkov, S.A. Maslyaev, V.N. Pimenov

A.A. Baikov Institute of Metallurgy and Material Sciences, Russian Academy of Sciences, Moscow, R.F.
The Moscow Physical Society, Lenisky Prospect 49, Russian Federation

Abstract

The report presents the results of numerical simulations of thermal processes in plasma focus experiments using a quasi-two-dimensional hydrodynamic program. The strong increase in the duration of the thermal processes observed in the experiments is explained.

Plasma Jet for Material Irradiation and Fuelling the Tokamak

A.V.Voronin1, A.V. Ankudinov[1], V.K.Gusev[1], Ya. A. Gerasimenko[2], E.V. Demina[3], G.S. Kurskiev[1], I.V. Miroshnikov[2], E.E. Mukhin[1], A.N. Novokhatsky[1], Yu.V. Petrov[1], N.V. Sakharov[1], Yu.V. Sudenkov[4], S.Yu. Tolstyakov[1]

[1] *A.F.Ioffe Physical-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia*
[2] *St. Petersburg State Polytechnical University, St. Petersburg, Russia*
[3] *A. A. Baikov Institute of Metallurgy and Material Sciences (IMET), Russian Academy of Sciences, Moscow, Russia*
[4] *St. Petersburg State University, St. Petersburg, Russia*

Abstract

Results of development of coaxial accelerator of intense hydrogen plasma jet are reported. Electric discharge passing through titanium hydride grains released pulsed gas cloud and supplied the accelerator for plasma jet generation. Stable operation of the source with the highest kinetic energy of pure hydrogen plasma jet during the current pulse was obtained. Behavior of the discharge in coaxial accelerator was studied. The highest energy of the plasma jet was obtained with polarity on the electrodes similar to the plasma focus. Plasma density near irradiated sample reached 4×10^{22} m^{-3}. Power density reached values of 130 GW/m^2 in 10 μs. Diagnostic methods for controlling the high-energy parameters of the plasma jet in material irradiation on the test bench plasma gun facility was performed, such as: density, velocity, pressure, power density, spectral composition.

Several tungsten (monocrystal, hot-rolled and powder made) were irradiated by a plasma jet with a power density of 25 and 78 GW/m^2. In all cases the molten material to a depth of a few micrometers was observed. Tungsten ITER_D_2EDZJ4 was the most resistant to damage. The powder made and mono-crystal tungsten types acquire regular structures with a characteristic particle size of ~ 100-200 nm at power density 78 GW/m^2.

By means of an advanced gun successful experiments on injection of a plasma jet in a tokamak magnetic field and plasma were made. A visible fact of penetration of the jet in tokamak plasma by video and streak cameras was demonstrated. The jet consists of several components and penetrates deep far inside of separatrix. Inside of tokamak plasma the measured jet velocity reached few tens kilometers per second. Passing over tokamak plasma the injected jet spreads along magnetic field lines. These results open a possibility of q-profile measurements. Full profiles of temperature and plasma density along minor diameter of tor before and after injection were measured. Experimental data on profile modification of tokamak plasma density and temperature by means of jet were observed. Possibility of controlling of discharge burning in tokamak by means of high kinetic energy plasma jet was shown. Injection can cause moderate growth of density (to 30 %) in the tokamak plasma central region without discharge degradation. The achieved results approve a perspective of the research for tokamak fuelling and parameter control.

The work is supported by the IAEA Research Contracts No: 16939, 16960, RFBR grant 11-08-00813-a, RF Ministry of Education and Science contracts No. 14.518.11.7004, No. 11.G34.31.0041.

Characterization of plasma bursts from a hundreds of joules plasma focus and its applications to study the effects on Si and W targets

Leopoldo Soto[1,2], María José Inestrosa[1,2], Gonzalo Avaria[1,2], José Moreno[1,2], Cristian Pavez[1,2], Ariel Tarifeño[1,2], Gonzalo Gutiérrez[3], Esteban Ramos-Moore[4], Julio Vergara[5], Fermín Castillo[6], Julio Herrera[6], Horacio Bruzzone[7] and Alejandro Clausse[8]

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[2] Centro de Investigación y Aplicaciones en Física de Plasmas y Potencia Pulsada, P[4]
[3] Departamento de Física, Facultad de Ciencias, Universidad de Chile
[4]Facultad de Física, Pontificia Universidad Católica de Chile
[5]Facultad de Ingeniería, Pontificia Universidad Católica de Chile
[6] Universidad Autónoma de México
[7]Universidad de Mar del Plata y CONICET, Argentina
[8]Universidad del Centro, CNEA y CONICET, Argentina
lsoto@cchen.cl

Abstract

The characterization of plasma bursts produced after the pinch phase from a plasma focus of hundreds of joules using optical refractive techniques is presented. A pulsed Nd-YAG laser at 532nm and 8ns FWMH pulse duration is used to obtain schlieren images and interferograms at different times of the plasma dynamics. An estimation of the energy and power of the bursts were obtained. Thus, this information was used to study the accumulative effect of several plasma bursts on targets of Si and W. Complementary, different existing approaches to simulate the radiation damage by molecular dynamics are being studied.
Supported by IAEA-CRP contract 16996 and bilateral project CONICYT, Chille – ANPCyT, Argentina "Innovative concepts for nuclear energy. Fusion-fission symbiosis" ACE-01.

Thermal Fatigue and Thermal Shock Response of Plasma Facing Materials and Components

M. Wirtz, J. Linke, Th. Loewenhoff and G. Pintsuk

Forschungszentrum Jülich GmbH, EURATOM Association, 52425 Jülich, Germany

Abstract

Plasma facing materials and components in a fusion device have to withstand severe environmental conditions such as thermal loads and particle fluxes. These exposure conditions may cause a deterioration of the material's and/or component's heat removal capability which, in the worst case, would lead to damage and long maintenance shut down of the machine. In order to ensure that the chosen candidate materials and component designs are suitable for an application under such exposure conditions detailed qualification programs are required. Especially the high steady state and transient thermal loads, simulated with the electron beam devices JUDITH 1 and 2 which are also capable of handling Beryllium and activated materials, will induce a wide range of surface modifications and damages on the plasma facing material's surface as well as the whole component.

Steady state loads with a power density of 5 – 10 MW/m² that last for several hundred seconds (with occasional slow transients of ≤ 20 MW/m² for < 10 seconds) have an influence on the joint between plasma facing material (PFM) and heat sink due to low cycle thermal fatigue. The most mature concept, a tungsten monoblock design, proofed to survive 1000 cycles at 18 MW/m² without degradation, even after an ITER relevant neutron irradiation of 0.6 dpa.

Transient heat loads in the form of edge localized modes with power densities of 1 – 10 GW/m² that last for 0.2 – 0.5 ms, but repeat with frequencies of > 1 Hz, will have an impact on the surface condition of PFMs (cracking, erosion, melting). Different tungsten alloys are typically compared by testing samples using a small number of transient loads. Material performance is compared for different intensities and at various base temperatures, exploring the damage threshold (intensity below which no surface modification occurs) and the cracking threshold (temperature above which the material roughens instead of cracking). High pulse number ($\leq 10^6$, ITER relevant) tests show a damage threshold of < 0.27 GW/m² for pure tungsten (grains oriented parallel to the surface) at base temperatures up to 700 °C. Open issues are the performance under high cycle transients after/during neutron irradiation, after recrystallization and under simultaneous particle flux (D/T/He). For DEMO new heat removal technologies will be necessary, as well as investigations at much higher neutron doses of ~20 dpa.

TiN and Ti-Cu-N Coated Stainless Steel by Using a Low Energy Plasma Focus Device

H.R.Yousefi, K.Mikhaili Agha, Neda Aghababaie, M.Ghoranneviss, A.Salar Alahi, S.Mohammadi and R.Arvin

Plasma Physics Research Center, Science and Research Branch, Islamic Azad University, Tehran, Iran

Abstract

In this research, coating of TiN and Ti-Cu-N on the stainless steel substrate was investigated in an attempt to investigate whether we can use the hardness property of TiN and Ti-Cu-N against erosion to increase the lifetime of the mirrors used in plasma diagnostics equipment. Firstly, two similar S.S.316L samples were chosen for this purpose. One of the samples was coated with TiN by using a DPF device, while the other was kept intact as a reference. In order to study the coating effects, these samples were exposed to 200 shots of hydrogen plasma with a total duration of 7 second in a tokamak. Before and after exposure, samples were analyzed by using atomic force microscopy (AFM), scanning electron microscopy (SEM), X-ray diffraction (XRD) and a spectrophotometer. It was found that the uncoated sample was severely damaged, its reflection dropped significantly, and it developed some cracks and lines, while no significant change was observed on the surface characteristic of the coated sample. Moreover the weight loss of the uncoated sample was higher in comparison to the coated one. Therefore the results of this experiment showed that the coating of stainless steel by TiN using a DPF device is a useful method to strengthen it against plasma erosion and with further optimization it could possibly be used in preparing plasma diagnostics mirrors.

Advances in the program of plasma focus scaling research and miniaturization of plasma focus devices

Leopoldo Soto[1,2], Cristian Pavez[1,2], Gonzalo Avaria[1,2], José Moreno[1,2], Cristian Pavez[1,2], Ariel Tarifeño[1,2], Francisco Molina[1,2], María José Inestrosa[1,2], Biswajit Bora[1,2], Jalaj Jain[1,2,3], José Pedreros[1,2,4] and Luis Altamirano[5]

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Abstract

Advances in the program of plasma focus scaling research and miniaturization of plasma focus devices developed at the Chilean Nuclear Energy Commission are presented. In particular, recent results obtained in an updated plasma focus device of a few joules, PF-2J, are presented. The update includes a compact capacitor bank of 160nF designed and constructed specially with the purpose to produce a portable plasma focus device of few joules for field applications. In addition, a discharge chamber with optical windows was designed and constructed to study the plasma dynamics. Preliminary results from optical refractive diagnostics, obtained with a Nd-YAG laser of 170ps, of the plasma dynamics in the PF-2J are presented.

Supported by CONICYT grant ACT 1115.

Fusion of ^{3}He with ^{3}He inside a Medium Energy Plasma Focus Device

Ram Niranjan[1], R K Rout[1], R V Kolekar[2] and R Srivastava[1], Satish C Gupta[1]

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[2]*Radiation Safety Systems Division, Bhabha Atomic Research Centre, Mumbai, India – 400 085*
Electronic mail: satish@barc.gov.in

Abstract

^{3}He is conceived as the third generation fusion fuel. Helium-3 (^{3}He) as a fusion fuel is attractive because of **aneutronic** nature of its reaction products. The fusion products alpha and proton can be contained using electric and magnetic fields. These particles will not induce any radioactivity in components of the reactor vessel. The fusion products can directly be used for the electricity generation. The plasma focus device is a well known laboratory fusion device. It has been reported to produce neutrons due to D-D or D-T fusion reaction. Fusion of heavier elements is difficult to achieve in laboratory due to high coulomb barrier of penetration for fusion. One such type of fusion was attempted for the first time here using a compact 11.5 kJ (40 μF, 24 kV) plasma focus device operated with high purity ^{3}He gas at 4mb of filling pressure. The fusion product proton and ^{4}He generated during the reaction of $^{3}He(^{3}He,2p)^{4}He$ inside the plasma focus device were recorded using CR-39 (with 24 μm thick aluminum filter) and lexan solid state nuclear track detectors respectively. The observation of tracks in lexan film (for ^{4}He) and in CR-39 film (for proton) suggests the occurrence of fusion reaction of ^{3}He with ^{3}He. The estimated ratio between the observed fusion products is close to expected ratio in such reaction. The results suggest fusion reaction is due to beam target mechanism.

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Radiative Cooling and Collapse-Comparative study of a range of gases

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e-mail: djxxx_1@yahoo.com

Abstract

A recent paper showed the effects of radiative collapse on the Kr plasma focus PF computed from the Lee Model code [S Lee, S H Saw and Jalil Ali, J Fusion Energ (2013) 32: 42-49]. In this paper we carried out series of numerical experiments in NX2 on H_2, D_2, He, N_2, Ne, Ar, Kr and Xe in order to compare the effect of radiative cooling and collapse on PF operation in these gases. The results are shown in the following graphs.

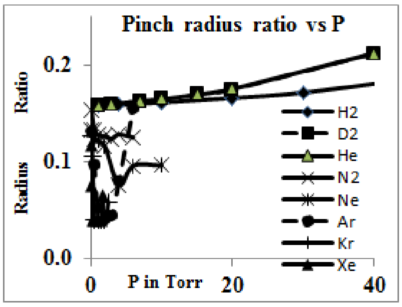

Fig 1. Pinch Radius Ratios in various gases

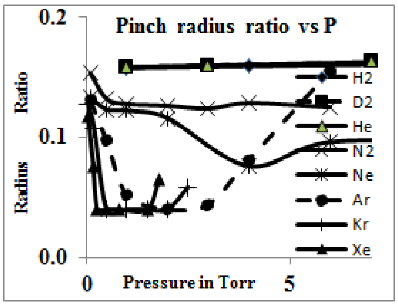

Fig 2. Magnifying the low pressure range

Fig 1 shows that the lightest gases H_2, D_2 and He have radius ratios (r_{min}/a where r_{min} = minimum pinch radius;'a'=anode radius) which rises from 0.15 towards 0.2 as pressure (P) rises. Fig 2 expands the lower P range to show that N_2 has a drop in radius ratio from 0.15 at 0.1 Torr to 0.13 at 1 Torr to 6 Torr. This drop in radius ratio is due to specific heat ratio SHR effects. Neon shows the same SHR effects until 2 Torr; then a further dip to 0.07 due to radiative cooling RC. For Ar SHR effect is apparent up to 0.2 Torr before RC plunges the radius ratio to 0.04 between 2 to 3 Torr. For Kr and Xe the radiative collapse is dominant over whole range of P. The RC is dominated by line radiative power $dQ_L/dt \sim Z_{eff}^2 Z_n^4 r_p^{-2}$ where Q_L=emitted energy accounting for plasma self-absorption, Z_n= atomic number, Z_{eff} = effective charge number and r_p= PF pinch radius. Taking the radiative power of Ne as 1, those of Ar, Kr and Xe are evaluated to be respectively 61, 2600 and 7500.

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Plasma Focus Ion Beam Properties- for Various Gases

S Lee[1,2,3] & S H Saw[1,2]

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Abstract

An earlier paper derived much needed benchmarks for deuteron beam fluence and flux in a plasma focus (PF) and discussed scaling trends with respect to device energy. In the present work we start from first principles, derive the flux equation of the ion beam of any gas; link to the Lee Model code and hence compute the ion beam properties of the PF. The flux equation shows a simple dependence on $(MZ_{eff})^{-1/2}$, if all other pinch properties remain equal (M=mass number and Z_{eff}=effective ionic charge). From this simple dependence one would expect the flux and fluence to reduce as we progress from H_2 to D_2, He to Kr and Xe. However, the pinch properties, primarily the pinch radius r_p does change drastically for different gases at different regimes of operation; due to thermodynamic and radiative effects. The change in r_p and associated and consequential changes in pinch dynamics and other properties, as computed from the code we use in this paper, have profound effects on modifying this simple dependence. The results show that, for a given PF, the fluence, flux, ion number and ion current decrease from the lightest to the heaviest gas except for trend-breaking higher values for Ar fluence and flux. The energy fluence, energy flux, power flow and damage factors are relatively constant from H_2 to N_2 but increase for Ne, Ar, Kr and Xe due to radiative cooling and collapse effects. The ion beam (FIB) energy has a narrow range of 4-8% E_0 showing a slight drop from H_2 to N_2; then having a slightly higher range of values for the radiative collapse gases Ne to Xe and being highest for Ar. The fast plasma stream energy rises from 8% E_0 for H_2 to 15 % for Ne then drops for the severely radiation-collapsed gases Ar, Kr and Xe, being lowest for Kr and Xe at 3-4%. Plasma focus research has thus far not produced any quantitative results that show correlation of ion beam properties among gases. This paper provides much needed benchmark reference values and scaling trends.

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