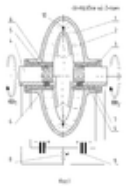
Centrifugal z-pinch

Abstract

FIELD: medicine.
SUBSTANCE: invention can be used as pulsed neutron and x-ray radiation source. Device consists of pulse power supply and gas-discharge chamber with electrodes and hydrogen isotopes. Electrodes are made in form of coaxial located one in another conducting bodies of revolution with curvilinear form. Around inner electrode-anode current lead there is an insulator with diameter smaller than that of working part of anode and cylindrical surface between electrodes ends in chamber. Cathode-chamber housing current lead is located near its central hole, through which insulator and anode current lead are passed. For cathode and anode additional current leads and insulator are made in mirror symmetry near cathode central hole respectively. Two anode current leads are tubular with mirror symmetric multithread spirals from inclined slots filled with solid insulators. Spirals are arranged vertically in zones of opposite corresponding gaps between electrodes ends in chamber.
EFFECT: technical result is increase of thermonuclear efficiency.
1 cl, 1 dwg

Images (1)



RU2586993C1
RU Grant

Find Prior Art Similar

Other languages: Russian

Inventor: Сергей Викторович Севцов

Original Assignee: Сергей Викторович Севцов

Priority date : 2015-04-07

Family: RU (1)

Date	App/Pub Number	Status
2015-04-07	RU2015112392A	
2016-06-10	RU2586993C1	Grant

Info: Patent citations (4), Similar documents, Priority and Related Applications

External links: Espacenet, Global Dossier, Discuss

Claims (1)

translated from Russian

The plasma source of penetrating radiation, consisting of a pulsed electric power source and a discharge chamber filled with hydrogen isotopes and containing discharge electrodes are formed in a coaxially arranged one inside the other conductive bodies of revolution with a curved generating lines around the current lead internal electrode - the anode is set insulator having an inside chamber between the ends of the electrodes an outer cylindrical surface with a diameter smaller than the diameter of the working part of the anode, cathode current lead - camera body is placed near its central hole through which the omitted insulator and the current lead of the anode, wherein the cathode and anode mirror-symmetrically formed additional

current leads and an insulator respectively near additional central cathode holes, besides two current lead anode are tubular with specularly symmetrical multistart helices of the inclined slits filled with a solid insulator, wherein the spiral is located at a height in areas opposite the respective gap between the ends mi electrodes in the chamber.

Description

translated from Russian

The described invention relates to a plasma technique, in particular to a device with a configuration Z-pinch, and may be applied as a pulsed neutron source and the X-ray radiation.

Known pulsed X-ray source: Patent RU №2315449 C1, 13.06.2006, Selemir Victor D. Repin Pavel Borisovich Orlov, Andrei Petrovich, Pikulin Igor V. "An apparatus for producing a dense high-temperature plasma in Z-pinch, cl. IPC H05H 1/06, publ. in BI №2, 2008, the patent holder - the Russian Federation represented by the Federal Agency for Atomic Energy (RU), Federal State Unitary Enterprise "Russian Federal Nuclear Center - All-Russian Research Institute of Experimental Physics" FSUE "VNIIEF" (RU) (Sarov). The apparatus comprises a switching power supply, an evacuated working chamber with two electrodes. The electrodes are mounted on a single axis at a distance from each other. Between them is axisymmetric laynerny cascade system comprising electrically conductive elements with twist angle φ_1 relative to the axis of the cascade. On the other diameter is arranged coaxially between the electrodes, at least one laynerny cascade system comprising electrically conductive elements with opposite twist angle φ_2. The electrically conductive elements are made of straight or helical wires, foils, as deposited on the substrate metal layer or a combination thereof. The angle of twist of conductive elements in one stage is selected to be $0 < \varphi_1 \leq 60°$, and in another stage - $60° \leq \varphi_2 < 0°$. Described device operates as follows analogue. By applying an electrical voltage from the pulse source to a two-stage power laynernuyu load current begins to grow through twisted in opposite directions multiwire cascades. In this configuration, the magnetic field of the current gains in addition to the azimuthal component of the axial component which is mainly concentrated in the annular area between the cascades. Upon subsequent evaporation of current rise occurs conductive elements to form a two-layer liner plasma liner. The magnitude of the discharge current reaches megaampere values - in the specific case about 20 MA. In what follows the widening of bilayer laynernoy current system leads to its acceleration in a radial direction toward the central axis of the chamber. If, for example, a system formed of helical wires, then the middle chamber plasma jet flies in the form of a compact double-layer cylinder. After power failure the inertia of the plasma cylinder collapses to heat energy transfer to the plasma X-ray pulse. The configuration of the double layer cylindrical Z-pinch, on the one hand, leads to the appearance in the plasma liner "shear" magnetic field (i.e., the resulting magnetic field lines have the twist angle of which varies across the thickness laynernoy system), and the azimuth is acquired torque. The presence of the "shear" the magnetic field and torque plasma contributes to the suppression of damaging magnetohydrodynamic (MHD) instabilities. These factors determine the feasibility of high resistance radial contraction Z-pinch in the described analog maintaining the original axial symmetry (dual-layer plasma cylinder and at the beginning and at the end of the pinch). On the other hand, the presence of character - no internal male cascade axial magnetic field counteracting radial implosion process of a multistage cylindrical Z-pinch, - the experimentally confirmed fact causes growth efficiency (coefficient of performance) X-ray source.

The totality of features of the first analog, similar to the set of essential features of the claimed device:

1) pulse electric power source;

2) a discharge chamber with two electrodes;

3) two multistart spiral set height in the gap between the ends of the electrodes in the chamber.

The reasons impeding obtaining a desired technical result of the claimed invention, - increase fusion efficiency, following the implementation of the first analogue:

1. Two opposite twisted spiral made of multistart exploding wires in the discharge chamber.

Accordingly, the creation of "shear" azimuthal magnetic field and torque plasma results in the filling of the discharge chamber analog ions of electrically conductive refractory material with a large atomic number Z (tungsten, for example). In this case it loses its meaning administered gaseous hydrogen isotope into the chamber between the electrodes for fusion reactions in the Z-pinch discharge, because the plasma from the vaporized coils act as the impurities increase in quenching temperature fusion plasma.

2. The coaxial arrangement of two oppositely swirling multistart spiral and one discharge gap between the electrodes.

The use of two oppositely swirling current coils generates two-layered current-plasma sheath at the beginning of the pinch. On the other hand due to a discharge gap between the electrodes of the current-plasma sheath cumulation analog front surface is a plasma volume - the same cylinder, as in the classical Z-pinch, and with only the rotating circumferential cavity in the middle. In this case there is a technical contradiction - the rotation of the "shear" and the torque of the whole plasma facilitate radial compression of the plasma by suppressing MHD instabilities and at the same time prevents compression due to the emergence of centrifugal force and power selection for the creation of spin. To improve the efficiency of the installation need to rotation of the plasma has been used not only for creating shear and torque - quenching MHD instabilities, but also directly to the plasma compression.

Also known pulsed neutron source: AS №1448993, VM Bystrytsky, MM Fix and VG Tolmachev, "pulsed neutron source", cl. IPC H05H 5/00, publ. in BI №32, 1992 Source terminal to twist the plasma sheath in the azimuthal direction comprises a sealed housing, in which two coaxial cylindrical electrodes coaxially arranged, electrically insulated from one another, the pulse current source connected through the switch to the center electrode - the anode, and the impulse inlet deuterium gas or plasma system. The outer cylindrical electrode - the cathode is mounted on one end face of the end wall of the housing and electrically connected to the common bus. The end portion of at least one of the cylindrical electrodes is formed as a multi-start helix, the helix angle of approach α, happy spiral length of section $1_{cn,}$ m, and a spiral diameter d, m, is chosen from the condition: $2d \geq 1_{cn} \geq 5 \cdot April^{10} \cdot d \cdot I^{-1} \cdot tg\alpha$, where I - the pulse current source the current source A. The variant in which the end portion of the second electrode is also formed as a multi-start helix whose length corresponds to the length of the spiral portion of the first electrode, and the approach angle It is equal in magnitude and opposite in sign to the corner entry and the first coil.

The device according to the second analog follows. At the initial time the power source is charged. The switch is open, the entire device is evacuated to a working vacuum inlet valve is pulsed system deuterium gas or plasma closed. The required time is activated, the valve and into the region between the anode and the cathode is injected calculation portion deuterium gas (or plasma). After the calculated and controlled by the delay time determined by the speed of the filling gas (plasma) of the annular gap between the anode and cathode triggered switch and a high voltage is supplied to the anode. As the anode current begins to flow, creating around the anode azimuthal magnetic field. As a result of the electrodynamic interaction of this field with the plasma current, defined by the Lorentz force, the current-plasma sheath begins to move to the end device, capturing (raking) in the process gas on its path and as a result of ionizing it. On admission to the end portion where the cathode (or the anode, or both) is designed as a multi-start spiral reverse current flowing spirally generates the azimuthal component of the magnetic field. As a result, the current-plasma sheath acquires initial azimuth point movement, the end twist is retained even when removal of the plasma by the ends of the electrodes. After removal of plasma produced relatively steady plasma vortex by the ends of the electrodes.

Due to the more stable plasma configuration - noncylindrical vortex second analogue compared to classic cylindrical Z-pinch increases the efficiency of the fusion analog installation.

Stability is due to the following non-cylindrical vortex. Vortex itself has a peculiar form of a torus. Below this torus restricted annular convex to the plasma, the current-plasma sheath previously acted as the magnetic piston. Top plasma torus is also limited by the annular, concave but to confine plasma, a second current-plasma sheath. The second current-plasma sheath was the result lynching emitted plasma in high-current discharge (discharge current characteristic value corresponds megaampere values) to form a single dense rotating vortex. Between the two curved surfaces are vortex plasma torus geometrically complemented by two annular surfaces. The larger vortex ring corresponds to a contact with the cathode. Ring smaller vortex contact corresponds at the anode center. The presence of the pinch plasma vortex promotes damping torque MHD instabilities compressible and confined plasma, in the image as in the case of the first analogue.

Analysis of plasma current with a helical magnetic field (p. 225-226; Artsimovich LA, Sagdeev RZ Plasma Physics for Physicists - M .: Atomizdat, 1979. - 320 p..) indicates that the current the system is not focused on the idealized geometry of the pinch on the surface of the plasma bunch, and distributed in any way by the surface cross-section of the plasmoid. In this plasma coexist within the axial and azimuthal components of the screw pitch. Due to the fact that the pitch of each magnetic surface in different plasma tube current "entangled" with the radial displacement (called br) arises anti quasielastic tensile force.

As seen from the assay described in the second analogue br also develops on two current-plasma membranes plasma vortex with its input, similar to the first analogue, in compression and stabilization plasma confinement.

The totality of features of the first analog, similar to the set of essential features of the claimed device is the following:

1) pulse electric power source;

2) a discharge chamber filled with hydrogen isotopes and containing discharge electrodes;

3) discharge electrodes are arranged coaxial to one another electrically conductive bodies of revolution;

4) an outer cathode electrode, an inner anode electrode;

5) having two oppositely-twisted not destroyed during discharge multistart conductive spirals.

The reasons impeding enhance fusion efficiency, during operation - a second analog follows.

1. As in the first analogue, in a second analogue centrifugal force is not used for the compression of the plasma on the rotational motion of the plasma and prevent pinch effect. The truth, the selection of spin energy of the plasma, in contrast to the first analog offset by mutual attraction unidirectional currents at the side - divided electrode pads - surfaces vortex. In the first analog axial components of the currents that are responsible for plasma spin, on the side surfaces of the cylinder have opposite directions - like a kind of multiple-coil - and, accordingly, do not stack, the currents in the pinch.

2. No magnetic well - an upper current-plasma sheath of the plasma vortex, the convex side of the plasma.

As is generally known (p. 218-219; Artsimovich LA, Sagdeev RZ Plasma Physics for Physicists - M .: Atomizdat, 1979. - 320 p.). - closed magnetic trap for the following theorem. It is impossible to create a magnetic field whose intensity increases outwardly from the plasma boundary near each point of the surface configuration of the toroidal plasma. Plasma itself due to its diamagnetism tends to spread in the direction of the weaker magnetic field. Therefore, if the surface of the plasma confined by the magnetic field whose intensity decreases outward from the plasma boundary, the boundary position plasmoid can be unstable. Moreover, for systems with low pressure plasma (e.g. - tokamak) this position - is not critical.

Pinch system for the Lawson criterion, in principle, you can not create a low pressure plasma fusion.

Due to the above discussed magnetic confinement of part of the plasma will decrease instability of the plasma torus, and will be disruption of the compression process. It turns out that the idea of pinching total 100% thermonuclear plasma volume for plasma volume around the maximum operating parameters (temperature and density) in a rotating noncylindrical Z-pinch in the second analogue not realized.

3. Technical infeasibility embodiment of the plasma focus at one coaxial gas discharge gap.

Since the magnetic trap in the second analogy is not perfect, it is possible, as an option, to apply the famous inventive method - Blessing in disguise. That is to use targeted release of part of the plasma due to the collapse unclosed current-plasma sheath, for example, for plasma focusing. However, in the analogue at a coaxial gas discharge gap can create only one whole plasma vortex. In this case, with one rotating plasmoid when trying to focus the organization there is a technical contradiction - the technical infeasibility of two opposite movements - centripetal and centrifugal. So that the focus occurs in the apparatus-analogue current-plasma sheath must first clot to collapse along the center axis of the anode. On the other hand, as a result of the formation and heating of the plasma vortex all particles acquire a rotational movement and centrifugal forces arise respectively, deflecting particles from a plasma anode central axis coinciding with the axis of rotation of the vortex of the plasma.

4. Location multistart spirals on the ends of the electrodes.

Unlike the first analog second analog multistart spiral conductive to generate axial magnetic field components are not destroyed during discharge. Positive moment resulting from this, with respect to fusion devices is clear that the metal impurities from the coils do not contaminate the plasma. But unlike the first analogue plasma twisting it occurs only in the final stage of the pinch. It turns out that the heating phase (disperse) current-plasma membrane and is not applicable br azimuthal torque to stabilize the plasma MHD instabilities.

It can not be solved besides the problem of increasing energy expenditure in parasitic inductance discharge chamber for increasing the energy deposited into the discharge. If not taken into account the existence of spiral slits at the ends of the electrodes, a pulse of the working gas inlet or plasma through a quick-acting valve and the presence of the unit casing, instead of the cathode casing was - setting the second analog similar in configuration meyzerovskogo plasma focus type. We can say that the two systems principle, to the final stage of discharge work the same way - a coaxial plasma accelerator.

In the plasma focus type, there meyzerovskogo drawback with electrical nature, consisting in limiting the discharge current rise with increasing energy installation with a constant operating voltage, which eventually leads to saturation of the neutron yield (p. 5, VY Nikulin, SN Poluhin "on the question of the plasma focus neutron of scaling. Electrical approach." FIAN Preprint №12, Moscow 2006). Since power increase at constant voltage battery charge accompanied by increase in the number of capacitors connected in parallel, which leads to a drop in battery inductance. On the other hand an increase in battery capacity leads to an increase in the discharge duration and the inevitable increase in the length of the electrodes of the discharge chamber to maintain matching conditions the moment of arrival of the current sheath to the axis of the apparatus with a current maximum. As a result, there comes a time when the amplitude of the current is already determined by the inductance of the camera, instead of the capacitor bank. Moreover, a further increase in battery capacity is not accompanied by an increase of the discharge current, due to increased inductance chamber. It occurs discharge current saturation and hence saturation of the neutron yield. Increased energy plazmofokusnyh plants (as applied to an analog of the claimed invention can pereinachit - coaxial plasma accelerator) is normally carried out by increasing the storage capacity of the capacitor at a constant voltage battery charge, i.e., by increasing the number of parallel-connected capacitors. Since an increase in battery capacity leads to an increase in discharge duration, in order to perform the matching condition dynamics current-plasma sheath with a duration of a current pulse - accumulation (as applied to an analog of the claimed invention, - the formation of the plasma vortex) of the current sheath at the axis of the apparatus at the current maximum - must increase the length of the electrodes of the discharge chamber, which inevitably leads to an increase in inductance chamber. Thereby further increasing the capacity of the battery is not accompanied by an increase of the discharge current. It occurs discharge current saturation and hence saturation of the neutron yield.

Coaxial Plasma Accelerators are also well-known inherent disadvantage - the amplitude decrease plasma accelerating voltage of appreciable inductance increment working chamber during discharge, which is caused since the same relatively long rectilinear trajectory of plasma acceleration along the coaxial gap particles (pp 373-377, and a hot plasma. controlled nuclear fusion. SY Lukyanov. Monograph. Home edition of physical and mathematical literature publishing House. Moscow, "Nauka", 1975).

If we consider two of the above positions to lack energy efficiency - the counting efficiency of a thermonuclear plant, then the situation is obtained that until saturation growth neutron energy input into the plasma accelerator costs will be accompanied by parasitic power from the pulsed power supply to the proportional increase in the inductance of the gas discharge chamber. There is a technical contradiction - to put in the category of more energy plasma particles should pass at the same time a more elongated acceleration trajectory, but a straight section of the acceleration size coaxial accelerator, and hence its parasitic inductance increases.

The solution of this technical contradiction could be giving the plasma particles in the acceleration in the coaxial channel spiral motion. In contrast to the rectilinear motion of the plasma in the second analogue, spiral motion would allow for the same length of electrodes greatly increase the path of plasma acceleration. A similar phenomenon in the second analogue occurs at the end of the pinch - particles in the formed plasma vortex are runs that greatly exceed the dimensions of the electrodes and over which the particles are turned and dimensions of the toroidal vortex. But unlike the first spiral analogue plasma twist in the second analogue does not work even briefly at the beginning of the pinch.

As a prototype for the combination of features, the closest to the set of essential features of the claimed invention, the selected device to receive the pulsed x-ray and neutron radiation: AS №347006, NG Makeev, TI Filippov and NV Filippov, "The plasma source of penetrating radiation", cl. IPC H05H 1/06, publ. in BI №4, 1995 g. plasma source of penetrating radiation includes a gas-discharge chamber filled with hydrogen isotopes and comprising discharge electrodes and a pulsed source of electric power. The

electrodes are designed as coaxially arranged one inside the other rotating bodies with the conductive curvilinear generatrix, in the particular case is a voltage elliptic arc with a line segment, inclined to the axis of the chamber. The internal electrode serving as an anode is attached to a cylindrical input, surrounded by an insulator. Entering the inner electrode has a smaller diameter than the working part of the inner electrode. The insulator between the electrodes, for example made of Alundum has a cylindrical shape. On the outer electrode is the cathode, in the immediate vicinity of the insulator is cylindrical cavity. They are uniformly spaced around the circumference whose center is on the axis of the chamber and serve to bind the start of the discharge, for uniform current distribution in the discharge chamber.

The device-prototype follows. After the voltage pulse from the source to the anode insulator is formed near the cylindrical plasma shell having a fibrous structure. Under the action of electrodynamic forces plasma sheath extends from the insulator and is accelerated by the interelectrode gap to the focus area, which is located on the axis of the discharge chamber near the anode surface at a side of the chamber opposite to the insulator. Forming a plasma focus discharge at a source of neutrons and X-rays.

The totality of the prototype signs, similar to the combination of the essential features of the claimed following devices:

1) a pulsed source of electrical power;

2) the gas discharge chamber, filled with hydrogen isotopes and containing discharge electrodes;

3) electrodes are coaxially arranged one inside the other conductive bodies of revolution with a curvilinear generatrix;

4) The inner electrode is an anode;

5) at the same time serves as a cathode chamber housing;

6) is mounted around the current lead of the anode insulator having within the chamber between the ends of the electrodes an outer cylindrical surface with a diameter smaller than the diameter of the working part of the anode;

7) through the central aperture in the cathode insulator and passed current lead anode;

8) current lead cathode disposed near its central opening.

Obstacles to enhance fusion efficiency, the following when working prototype.

1. Lack of technical means altering the geometric structure of the plasma focus, which prevents improvement plazmofokusnyh installations.

As is known, the mechanism of formation of the plasma focus next. If the cumulation current-plasma sheath (page 36-37, Nikulin Valeriy Yakovlevich the manuscript on a manuscript -.. The thesis for the degree of Doctor of Physical and Mathematical Sciences "high-current discharge of type a plasma focus Physical processes and applications in technologies." Physical Institute. them. Lebedev, Moscow, 2007) on the axis of the chamber is a rapid compression (pinching) of the plasma near the anode surface to a minimum, for the time of pinch radius. During maximum compression of the pinch should be small extension, and on its surface develops Rayleigh-Taylor instability type constrictions of wavelength 2-10 times smaller than the total length of the plasma column, leading to occurrence of a second plasma compression. The diameter of the plasma column in the 1st compression 0.3-1.5 cm, 0.1-0.5 cm in the second. Due to the large mass of plasma leakage during compression up due netsilindrichnosti shell and release of the radius (due development of instabilities of the pinch) a significant part of the energy is transferred to the small amount of remaining material. In this mode the magnetohydrodynamic effective plasma heating under compression.

The resulting high temperature plasma zone is an intense source of radiation and is called a plasma focus.

The resulting plasma clot - plasma focus has a relatively small size compared with the size of discharge chamber plazmofokusnyh installations.

For example (p - 5;. 13, VY Nikulin, SN Poluhin "On the plasma focus neutron of scaling Electrical approach." FIAN Preprint №12, Moscow. 2006), in setting the PF-3 NFI RRC "Kurchatovsky Institute" focus the plasma column has a height of about 5 cm and a maximum diameter of about 1.5 cm pinch (as discussed above). At the same time the diameter of the cathode (i.e. - the gas discharge chamber housing) slightly more than one meter, and is equal to - 116 cm, and the diameter of the anode is equal to one meter. However, these values are given for no fusion modes - without deuterium in the chamber.

Besides example another source indicates that the characteristic dimensions of focus for fusion plazmofokusnyh (p. 613, Physical Encyclopedia / hL. Ed. Prokhorov Ed. Col. Alekseev DM, AM Baldin, AM Bonch- , Borovik-Romanov et al -. M .: Big Russian encyclopedia T. 3. magnetoplasma -.... Poynting theorem 1992. 672 s, yl) are in the range 0.01-3 cm.

It is also relatively small quantities compared to the size of the electrodes - to set the PF-400 Tulip LPI (page 45, Nikulin Valeriy Yakovlevich the manuscript on a manuscript -.. The thesis for the degree of Doctor of Physical and Mathematical Sciences "high-current discharge of type a plasma focus. .. physical processes and technologies used in "physical Lebedev Institute, Moscow, 2007) with a geometry Filippovskaya cathode diameter - 50 cm, and the diameter of the anode, respectively - 40 cm.

On the one hand, compared with the existing plasma pinch system focus is characterized by the high efficiency compression plasma (p. 613, Physical Encyclopedia / hL. Ed. Prokhorov. Ed. Col. Alekseev DM, AM Baldin, AM Bonch-, Borovik-Romanov et al -. M .: Big Russian encyclopedia T. 3. magnetoplasma -. Poynting theorem 1992. 672 s, yl), respectively, and higher energy density per unit... pinch volume. Thus, with the flat compression of the plasma density is increased approximately four times, in a cylindrical chamber in view of the reflection of the shock wave - 33 times, and in the case of focusing the partial mass ejection on a limited adjustment portion along the axis (e.g. - 5 cm for installation PF-3) the density is increased to 10^3 (in terms of reduction of entropy).

This characteristic - high efficiency pinch plasma focus indicates the feasibility of introducing a vortex in the plasma focus discharge installation according to the second analogue.

On the other hand, if only to take itself plazmofokusnuyu installation and to compare it to the magnitude of input energy to focus the total energy value obtained from the pulse power supply -, there are small quantities of the capacitor bank.

So developers and experimenters say (page 109, All-Union Institute of Scientific and Technical Information The results of the Science and Technology Series Plasma Physics Volume 2 Editor -.... VD Shafranov Moscow in 1981..) To focus the energy content of about 10% of the battery power.

Theorists talking about plasmoid that arises already at the second compression plasma predict (page 240;..... 243, of Plasma Physics, Collection of Papers, Issue 8. Edited by Academician MA Leontovich M. Atomizdat. 1974, p. 384.) only 3% of the energy input into focus on the value of the battery power.

Such small values of the relative energy input to the plasma focus can be attributed to the small mass of the plasma focus. If done in the cathode central bore (pp. 217-218, LA Artsimovich. Controlled Thermonuclear Reactions. State Publishing House of Physical and Mathematical literature. Moscow. 1961) and plazmofokusnuyu installation used as the plasma injector (plasma gun), the result of the first experiments on small low-power units quantity emitted mass "shell" has been obtained - a plasma focus, a few tenths of a percent of the total mass of gas in the discharge chamber.

Do not save the situation improving energy deposition in the subsequent plazmofokusnyh installations.

On installations megajoule range saturation observed (p 166-167; 173, Nikulin Valeriy Yakovlevich the manuscript on a manuscript - Thesis for the degree of Doctor of Physical and Mathematical Sciences "high-current discharge of type a plasma focus Physical processes and applications in technologies."... physical Institute. Lebedev, Moscow, 2007), neutron and hard X-ray output. Growth in the energy input to the discharge megajoule units not accompanied by an increase of penetrating radiation.

In other words, for any energy existing plazmofokusnye installation are relatively small in size and energy content of the plasma focus.

Obtained by the classical plazmofokusnyh plants occurs technical contradiction - on the one hand, it is necessary to ensure the most compact plasma focus, on the other hand - a compact linear pinch obtained when focusing leads to small values of percent the focused plasma percent of the energy input in the focus and impossibility growth of the energy input in megajoule areas.

2. Availability motion current-plasma membrane from the anode perimeter at the top surface to the center of focus.

It is generally known that the stabilization of plasma instabilities under certain conditions can be carried out spontaneously as a transition to a more energetically favorable state that occurs due to instability of particles and adjustment processes of energy transfer so that the current distribution implemented resistant. Such a plasma self-organization is shown most clearly in current systems -.... Tokamak and pinches with reversed magnetic field (pages 656-658, Encyclopedia of Physical / hL eds Prokhorov Ed count Alekseev DM, AM.. . Baldin, AM Bonch-, Borovik-Romanov et al -. M .: Big Russian encyclopedia T. 4 Poynting-Robertson-Tape, 1994, 704, yl)....

When plasma focus study with a spherical chamber, created as a special case of the prototype device, it was found that the initial phase of the plasma sheath movement DPCH from the insulator to the equatorial chamber zone obeys the laws envelope dynamics in reverse Z-pinch (Development and research spherical chambers Plasma . focus NG Makeev, Rumyantsev VG, GN Cheremuhin - site http://pandiaweb.ru/text/77/309/52969.php online publication Pandia.ru). This provides auto adjust the velocity of the various shell sections, and improves its axial symmetry.

In the prior art device, naturally, as in a plasma focus with a spherical chamber when moving current-plasma sheath on the insulator to the anode perimeter ellipsoid will also be observed Auto-speed movement of various shell sections, and improvement of its axial symmetry.

Unfortunately - more current-plasma sheath begins to move toward the center of the anode surface with decreasing radius and how its classic Z-pinch plasma becomes prone to instability of the beam waist.

3. Lack of technical means for creating shear and azimuth angular momentum of the compressed plasma.

Current-plasma sheath in the plasma focus settings and meyzerovskogo Filippov type as is well known has a concave form from the surface of the plasma. Under the pressure of the dynamic pressure of current-plasma sheath in the prior art device is also compressible convex toward the plasma. Automatically turns a kind of magnetic well, contributing to the suppression of MHD instabilities on the surface of the magnetic piston.

However, only the concavity current-plasma membrane enough to eliminate all of MHD instability, since the current-plasma sheath in the plasma focus setting itself compressible plasma have inhomogeneous structure with discontinuities density.

Current-plasma sheath at the initial stages of development of the plasma focus has a fibrous structure, which further leads to the development of unwanted plasma instabilities (pp. 93-95, the All-Union Institute of Scientific and Technical Information. Results of science and technology. A series of Plasma Physics. Volume 2. Editor - VD Shafranov Moscow, 1981).. At the time of applying a high voltage to the anode, an electric field with a maximum at the boundary of the cathode insulator. With this edge ionization wave begins to propagate along the surface of the insulator and extends to the edge of the anode. From this point of time the electric field is substantially constant and amounts to several kV / cm. The gas gap is the resistive load, wherein the growth continues conductivity due to the ionization of gas (deuterium). The presence of a small electric field gradient with distance from the insulator causes inhomogeneity sharp ionization - "ionization current skin effect" near the insulator. In this step, external signs are manifested gas discharge - nucleation anode spots, giving rise to the structure of the azimuthal current (current forming fibers), as well as the appearance of transverse striations. These striations correspond to interleaved portions of different density and the current temperature along the fiber. The resulting fibrous current-plasma sheath under the action of a ponderomotive force current starts towards the axis of the apparatus and pushes the front of a shock wave. During the movement of the current-plasma sheath shrinks, it takes the form of a funnel with a neck to the anode current and interlock fibers. When this stratum formed previously can initiate the development of MHD instability of the plasma column at the stage of the plasma focus.

In addition to transverse structures - striations are longitudinal azimuthal structures generated fibrous nature current-plasma membrane, preventing both formation of plasma focus and raking gas current-plasma sheath to the focusing axis (page 148, 149; 161, 163, Nikulin Valery Ya. the manuscript on a manuscript -.. The thesis for the degree of doctor of physical and Mathematical Sciences ". High-current discharge of type a plasma focus physical processes and applications in technologies", Physics Institute, Lebedev, Moscow, 2007). First is the "Triax". At the stage preceding the first compression, the current has a fibrous structure, the magnetic field near the axis multipole acquires character, and PF-axis current can be excited in opposite directions, which is confined to itself, forms a loop. This will lead to the inhibition of the formation of the plasma and at some time (up to resorption and this current dissipation) quasi-equilibrium configuration type "triaxial" with fibrous structure. Secondly, the structure of this filament current-plasma sheath. The absolute yield of hard radiation type plasma focus systems depends largely on how well the current-plasma sheath rakes working gas. The residual gas can cause secondary breakdown near the insulator and thereby shunt current flowing through the pinch. The reason for forming a second current sheath is connected with the first current filamentation shell, whereby it is not fully rakes working gas. In turn, causes a distortion of filamentation uniformity of azimuthal uniformity of the fiber structure current-plasma sheath, which is caused by two reasons: the presence of impurities in the current sheath made of structural material discharge chamber and the overheating of the shell. Impurities decrease conductivity shell, is increased, loosen its skin layer, which leads to the emergence of large-scale inhomogeneities. Overheating shell limit associated with the existence of limiting battery energy transfer per unit surface area of the plasma membrane and the working surface of the insulator above which develops so-called overheating instability.

Magnetic uncompensated pit could in plasma focus MHD instability to suppress, both in analog devices, due to shear of the current-plasma membrane and azimuthal torque compressible plasma. However, the installation of the prototype are no multiple-current spiral plasma twist.

4. Lack of shear negatively affect the working gas raking newly created plazmofokusnoy installation if only motion current-plasma membrane will be present in it, as in the reverse pinch - from the center to the perimeter of the shell with increasing radius.

The fact that the current prototype installation fibers initially diverge from each other on the lower side of the anode - as in the reverse pinch, but then still stick together when focusing on the upper side of the anode.

If only constructively to create conditions for the expansion of the gap between the fibers of the shell - that seepage raking working gas will not occur between the lines tangled fibers.

5. The axial linear motion of plasma particles upon heating.

The proposed system of electrodes in the prior art device provides an extended phase of accelerated plasma sheath in a coaxial movement gap (as at Mazer) and fleeting phase radial convergence to its axis of the chamber (as in Filippova). At the same time, a radial rectilinear motion current-plasma sheath at the extended phase of accelerated motion (by anode bottom) results, like the coaxial plasma accelerator to amplitude reduction accelerating voltage plasma due to noticeable increment of the working chamber inductance during the discharge, which is caused by relatively long rectilinear trajectory of plasma acceleration along the coaxial particle clearance. Like the second analogues and the prototype there is a technical contradiction - to put in the category of more energy plasma particles should pass at the same time a more elongated acceleration trajectory, but a straight section of the acceleration size coaxial accelerator, and hence its parasitic inductance increases.

6. Reducing the current-area plasma sheath during its descent to a collapse.

When fleeting radial convergence phase to the axis of the chamber, all the current-plasma sheath is located on the upper surface of the anode ellipsoid. When the current-descent of the plasma membrane, its diameter is reduced - is correspondingly reduced membrane area. A reduction in area can cause filamentation due to the risk of exceeding the limit, limiting battery energy transfer per unit surface area of the plasma membrane, and accordingly the overheating of instability.

7. Small area contact with the neck of the funnel plasma anode surface. Because of the small-area plasma funnel neck is vaporized metal anode surface with the release of the impurities obtained with high atomic number Z in the plasma, and as a result, decrease the plasma temperature.

The technical problem to be solved by the claimed invention, - from one side. radically change the geometry of a plasma clot in plasma focus setting and to increase accordingly the relative size of the size, volume and the input energy of the plasma focus, and on the other hand, the increase in energy consumption to compensate for greater plasma focus formation by means of:

1) suppression of MHD instability of the plasma by adding to magnetic shear pit plasma focus, the angular momentum of the plasma and the auto-speed movement of various portions of the plasma current-shells in their motion perpendicular to the cylindrical surface of the insulator with a symmetric vortex increasing radii;

2) improved raking working gas due to shear raking current-plasma membranes;

3) the use of centrifugal forces from the rotation of the plasma for the plasma compression;

4) the auto-speed movement of various parts of the current-plasma membranes and improve their axial symmetry;

5) reduction in the magnitude of the parasitic inductance of the camera and its numerical growth at pinch;

6) a significant growth area of the current-plasma sheath throughout its existence;

7) recycling the azimuthal components of the current-current plasma shell to collapse shells;

8) during growth of the pinch of the neck area of contact collapse current-plasma at the anode surfaces.

Technical result expected from solutions of technical problems in the implementation of the claimed invention - increase fusion efficiency setup discharge with upgraded plasma focus.

The stated technical problem is solved by installing a Z-pinch, having the following essential features characteristic coinciding with the characteristic features of the apparatus-prototype:

1) pulse electric power source;

2) a discharge chamber filled with hydrogen isotopes and containing discharge electrodes;

3) electrodes are coaxially arranged one inside the other conductive bodies of revolution with a curvilinear generatrix;

4) The inner electrode is an anode;

5) at the same time serves as a cathode chamber housing;

6) is mounted around the current lead of the anode insulator having within the chamber between the ends of the electrodes an outer cylindrical surface with a diameter smaller than the diameter of the working part of the anode;

7) through the central aperture in the cathode insulator and passed current lead anode;

8) current lead cathode disposed near its central hole, are added the following distinctive essential features:

1) on the cathode formed additional central opening;

2) for the cathode and anode formed specularly symmetrically additional current leads and an insulator respectively near this additional central hole of the cathode;

3), two current lead anode are tubular with specularly symmetrical multithread coils of the inclined slots;

4) helix arranged in height in areas opposite the respective gaps between the ends of the electrodes in the chamber;

5) inclined slits spirals filled solid insulators.

The collection of all essential features upgraded plazmofokusnoy installation results in the elimination of its variety of technical applications, which is the key to solving the technical problem of the claimed invention. If classical plasma focus can make a hole in the center of the cathode for the plasma shots columnar clots like projectiles in a plasma injector, the modernized pinch "shots" are made in the form of single rings on a circular perimeter around the anode. The use of the modernized pinch in the form of a plasma gun for pumping fusion of magnetic traps, plasma shots in the military electro-guns, plasma space rocket propellers specially eliminated.

To form the end of the pinch plasma focus as a ring around the perimeter of the working part of the anode current leads mirror symmetry axis of the cathode and anode in the early pinch, are centered Fitting two insulators two symmetrical current-plasma sheath. Further, these membranes move to the anode perimeter where face, starting from the soles, their side surfaces and form a pinch kvazitoroidalny.

The significant features of the new machines offer the creation of a ring of focus:

1) pulse electric power source;

2) a discharge chamber filled with hydrogen isotopes and containing discharge electrodes;

3) electrodes are coaxially arranged one inside the other conductive bodies of revolution with a curvilinear generatrix;

4) The inner electrode is an anode;

5) at the same time serves as a cathode chamber housing;

6) is mounted around the current lead of the anode insulator having within the chamber between the ends of the electrodes an outer cylindrical surface with a diameter smaller than the diameter of the working part of the anode;

7) through the central aperture in the cathode insulator and passed current lead anode;

8) current lead cathode disposed near its central hole;

9) formed on the cathode additional central opening;

10) for the cathode and anode formed specularly symmetrically additional current leads and an insulator respectively near this additional central hole of the cathode;

11), two current lead anode are tubular.

by increasing the size of the new annular plasma focus introduced measures for suppression of MHD instability of the plasma by adding to the system the shear a torque plasma and autoregulation of the axial velocity of the expanding symmetrically and perpendicularly from the cylindrical surfaces of insulators vortex current-plasma membranes to eliminate compensation in the form of energy input growth improve shoveling working gas due to shear the current-plasma sheath, the use of centrifugal forces from the rotation of the plasma for compression channel Atia plasma, reducing the magnitude of the parasitic inductance of the camera and its numerical growth at pinch utilization azimuthal components of the current the current-plasma shell to collapse shells, as well as measures to reduce the growth of the energy density on the surfaces of the current-plasma membranes and the anode surface up to the time counter collapse shells due to the marked increase in the current-plasma sheath area throughout its existence and

growth during the pinch of the neck area of contact collapse over the current-plasma awns at the anode. In other words, the increased energy efficiency of the plasma heating for the formation of the plasma focus.

It should be noted that the process of the auto-speed axial movements of flying symmetrically and perpendicularly from the cylindrical surfaces of insulators nonrotating current-plasma membranes occurs already when implementing the above eleven essential characteristic features of the claimed device.

All these effects (except, of course, - the Auto) for increasing the heating efficiency is achieved due to the vortex motion of the two current-plasma membranes throughout their existence, beginning with education and development around the cylindrical surface of the insulator and finishing joint clash with popping. The significant features of the new installation provide energy efficiency (in conjunction with the above-described essential distinctive features) - no growth of energy consumption for creation of focus ring:

1) two tubular anode current lead configured to specularly symmetrical multi-start helices of the inclined slots;

2) are arranged spirally in height in areas opposite the respective gaps between the ends of the electrodes in the cell.

To prevent parasitic discharge secondary coils around the current leads tubular anodes in a plant modernized plazmofokusnuyu added next essential feature.

1. Oblique slit coils filled with solid insulators.

The technical solution allows two current-generated plasma sheath to move along parallel coaxial annular channels in the form of expanding two mirror-symmetrical vortices and accelerated under the action of current ponderomotive forces and centrifugal forces. Due to the fact that the rotary current-plasma membranes present bs, while compressible plasma which is formed by the shock wave from the radial motion of the current-plasma membranes, azimuth torque - the conditions for quenching MHD plasma instabilities. Besides quenching MHD current-instabilities in the plasma membranes disclosed device contributes Auto-speed axial movements of their borders, with symmetrical emission arises perpendicularly from the cylindrical surfaces of insulators vortices these membranes. Due to entanglement of fibers with widely improved with working gas raking Autoregulated escape of current-plasma membranes. Since the particles in the current-plasma membranes are coaxial accelerating gaps swirling motion, it becomes possible not to increase the dimensions of the installation and consequently loss of the initial working chamber parasitic inductance and this inductance increase during discharge. Characteristically, the area of the two current-plasma membranes increases as the diameter increases during acceleration. Therefore, the conditions for the development of overheating instability will not occur. On the perimeter of one common for the two current-anode plasma membranes leading edges of the two side surfaces facing shells, it is their joint collapse and the formation of a plasma focus ring. As a result of addition of unidirectional azimuthal current components responsible for the rotation of the plasma in the vortices, the collapse of growth occurs pulsed magnetic field for focusing and thus pinch compensation lowering plasma translational speed of its motion in a vortex coaxial annular gaps modernized plant. Due to the fact that the neck of the funnel of the two side surfaces opposing the current-plasma membranes lies on the annular surface around the anode perimeter and no small point spot in the center of the anode, both in classical plazmofokusnoy installation, - evaporation of anode metal at the plasma accumulation of reduced to a minimum.

In summary, we have eventually increase the relative magnitudes of dimensions, volume and the input energy of the plasma focus without relative increase of energy consumption for creation of a new structure of the plasma, and hence increase the neutron and X-ray radiation at a predetermined energy.

Fusion efficiency increases - the technical result achieved.

The technical nature of the proposed technical solution is illustrated by drawings - FIG. 1, which shows the following elements:

1) a cathode;

2) the working part of the anode;

3) a cylindrical insulator between the electrodes;

4) The tube current lead of the anode;

5) unlocked multistart spiral conductive coil;

6) adjacent insulator multistart spiral turns;

7) a cathode current lead;

8) arrestor

9) High-low-inductive capacitor bank;

10) kvazitoroidalny plasma focus.

$\omega_1 = \omega_2$ -, respectively, equal in magnitude and direction of the angular rotation velocity of the plasma vortices two mirror.

Dotted lines show the cross section and position of the current-plasma membranes during their movement from the corresponding cylindrical surface of the insulator to the anode perimeter.

The cathode material - stainless steel. The cathode consists of two mirror halves which are joined together vacuum-tight (not shown).

Anode Material - Electrical copper.

The working surfaces of electrodes delineated using the ellipsoids of revolution.

As the insulator material between the electrodes is proposed to use a broker (pp 134-137, Balkevich VL Technical Ceramics: Textbook for technical colleges - 2-e edition, revised and enlarged - M .: Stroyizdat, 1984..... - 256 s, yl)... At normal temperature, thermal conductivity of insulating ceramics on the basis of thermal conductivity than the beryllium oxide and other oxide ceramic materials 7-10 times. Under normal conditions, the thermal conductivity of beryllium oxide as a thermal conductivity greater than a number of metals (steel, nickel, molybdenum, lead, etc.). However, with increasing temperature thermal conductivity of beryllium oxide as another oxide ceramic drops abruptly, but also at high temperatures (1500-1800 ° C) a thermal conductivity higher thermal conductivity BeO other ceramic oxide 1.5-2 times. Volatility sintered ceramics of beryllium oxide in vacuo virtually undetectable to 2000-2100 ° C.

plasma focus, it was proposed to replace the lateral dielectric surface with the classic Z-pinch on copper - At the time when the plant begins to create. Due to the better thermal conductivity of copper as compared with an insulator assumed and turned reduction of impurities in a pinch plasma.

could not be ruled out in the inventive installation of plasma contact with the insulator completely. Therefore, by analogy, it is proposed to increase the thermal conductivity of a surface of the discharge chamber. Not only by replacing the dielectric to the conductor, and increasing the thermal conductivity of insulators between the electrodes when using beryllium oxide. Radiation resistance of beryllium oxide such replacement allows - beryllium oxide as is well known, a good matrix material for nuclear fuel.

As materials for insulators filling the spiral slot on the tube current leads of the anodes can be used mica. mica flexibility makes it easy to fill in the curved groove slots. Not the last argument in favor of the use of mica in the claimed device - High radiation resistance mica materials.

However, as the materials for insulators filling the spiral slits in the tubular anode current leads can be applied and Teflon. On spirals current leads to achieve vacuum sealing is not necessary. Therefore, unlike solid ceramic insulators between the electrodes can be used for laying a flexible spiral dielectrics that technologically easier.

Claimed device operates as follows.

After the voltage pulse from the source to the anode through the gap near two insulators are formed two cylindrical plasma shell having a fibrous structure. Under the action of electrodynamic forces plasma membrane symmetrically away from the insulators. Due to the pulsed current in the coils multistart two current leads of the anode casing to acquire an existing axial additional movement - the rotational azimuthal. Due to this rotation of the plasma current-fiber membranes are mixed to form a shear. Two vortex to spin in two parallel coaxial annular gaps between the electrodes. The diameters of the vortex always increasing. Formed by two shock waves in front of the plasma membranes acquires torque. After a certain time the current-rotating plasma membrane under the action of the ponderomotive and centrifugal forces out his soles on the perimeter of the anode. Here are oppositely faced their side surfaces. The geometry of the chamber and the inductance of the capacitor bank are chosen so that the maximum current pulse coincides with the point of the meeting surfaces of the shells. Further there is a collapse of the formed wedge-shaped annular channel due to merger of helical currents shells with a vortex plasma outflow portion toward the inner perimeter of the cathode. Vortex leakage leads to the accumulation of plasma. Pinching effluent pinch, by analogy with the plasma focus, will be accompanied by energy transfer to the plasma part - to the resulting compact plasmoid - quasitorus in the claimed device. This focused quasitorus plasma is the source of neutrons and X-rays.

The claimed device is a kind of non-cylindrical Z-pinch, which paradoxically uses centrifugal forces and effects.

For this reason, the inventor named the inventive pinch installation - "centrifugal Z-pinch."

Patent Citations (4)

Publication number	Priority date	Publication date	Assignee	Title
US6728337B2 *	2001-06-07	2004-04-27	Plex Llc	Star pinch plasma source of photons or neutrons
RU2297117C1 *	2005-08-15	2007-04-10	Российская Федерация в лице Федерального агентства по атомной энергии	Device for producing impulse roentgen and neutron radiation
RU2342810C1 *	2007-05-17	2008-12-27	Федеральное государственное унитарное предприятие "Всероссийский научно-исследовательский институт автоматики им. Н.Л. Духова" (ФГУП "ВНИИА")	Plasma source of penetrating radiation
RU141449U1 *	2014-03-04	2014-06-10	Федеральное государственное унитарное предприятие "Всероссийский научно-исследовательский институт автоматики им. Н.Л. Духова" (ФГУП "ВНИИА")	The plasma source of penetrating radiation
Family To Family Citations				

* Cited by examiner, † Cited by third party

Similar Documents

Publication	Publication Date	Title
US3417245A	1968-12-17	Neutron generating apparatus
US4800281A	1989-01-24	Compact penning-discharge plasma source
US3613370A	1971-10-19	Ion thruster
US4201921A	1980-05-06	Electron beam-capillary plasma flash x-ray device
US4560528A	1985-12-24	Method and apparatus for producing average magnetic well in a reversed field pinch
US4350926A	1982-09-21	Hollow beam electron source
US4601871A	1986-07-22	Steady state compact toroidal plasma production
Morozov	2003	The conceptual development of stationary plasma thrusters
US4314180A	1982-02-02	High density ion source
US4233537A	1980-11-11	Multicusp plasma containment apparatus
US4912731A	1990-03-27	Plasma focus apparatus with field distortion elements
US5215703A	1993-06-01	High-flux neutron generator tube
US6777862B2	2004-08-17	Segmented electrode hall thruster with reduced plume
US4751429A	1988-06-14	High power microwave generator
US3664920A	1972-05-23	Electrostatic containment in fusion reactors
Oks et al.	1999	Development of plasma cathode electron guns
US20030223528A1	2003-12-04	Electrostatic accelerated-recirculating-ion fusion neutron/proton source
US7679025B1	2010-03-16	Dense plasma focus apparatus
US4076990A	1978-02-28	Tube target for fusion neutron generator
READER	1964	Experimental performance of a 50 centimeter diameter electron-bombardment ion rocket
Nikolaev et al.	2012	Upgraded vacuum arc ion source for metal ion implantation
US2961558A	1960-11-22	Co-axial discharges

Stirling et al.	1979	Magnetic multipole line-cusp plasma generator for neutral beam injectors
US20070237281A1	2007-10-11	Neutron generator tube having reduced internal voltage gradients and longer lifetime
Robson et al.	1959	Choice of materials and problems of design of heavy-current toroidal discharge tubes

Priority And Related Applications

Priority Applications (1)

Application	Priority date	Filing date	Title
RU2015112392A	2015-04-07	2015-04-07	Centrifugal z-pinch

Applications Claiming Priority (1)

Application	Filing date	Title
RU2015112392A	2015-04-07	Centrifugal z-pinch