Electronically driven neutrons synthesis-generator based on a standard four-cycle generator with the magneto-optical flow seal

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Abstract

The generation of the dense flow of protons, deuterium or tritium atoms for the neutrons synthesis on the ion-plasma target of deuterium, tritium or lithium occurs as the result of primary flow compaction and discretization by software-defined concentration and average energy of the flow. Flows are formed in strictly specified parameters T sequence period, n concentration and the frequency of discrete flows ω.

Synthesis-Generator

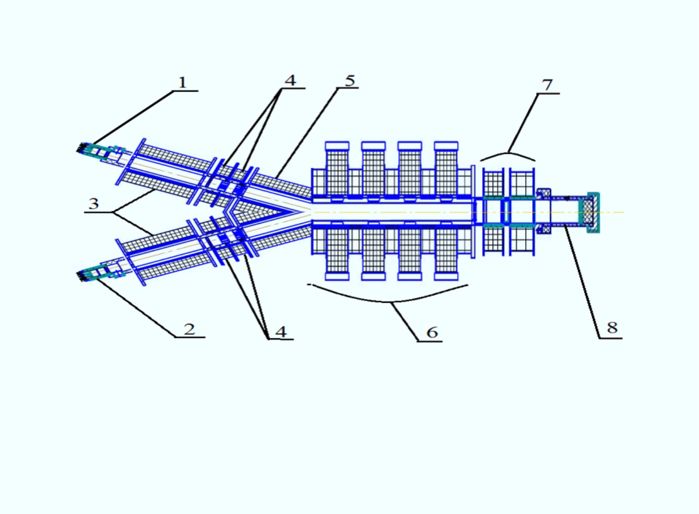

Figure: Synthesis-Generator.

Sections of Generator

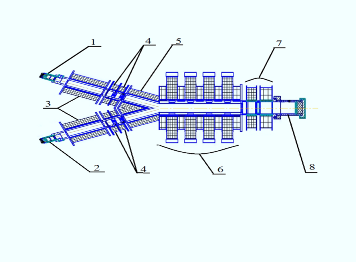

Figure: Sections of Generator.

1. Ionizer and deuterium and lithium
2. Injector
3. Linear pulsed accelerator
4. Magneto-optical ion accumulator of ^2H, ^7Li
5. Accelerator-accumulator
6. Magnetodynamic 4 cyclic camera
7. Magneto-optical drive-limiter
8. The system output neutrons

The structure of the generator

№	Node name	Node function
1	Ionizer of hydrogen, nitrogen and lithium	Ionization of hydrogen, nitrogen and lithium
2	Injector of hydrogen, nitrogen and lithium ions	Injector with 25 keV energy
3	Магнитооптический накопитель-формирователь ионов ^{1}H, ^{7}Li,^{14}N	Обеспечивают формирование дискретных потоков ионов в ускоритель
4	Magnetooptic storage device-flux shaper of ions	Forms discrete ion fluxes to the accelerator
5	Proton linear accelerator-shaper	For energy from 200 keV to 400 keV with electrostatic scanning of ions
6	^{7}Li linear accelerator-shaper	For energy from 200 keV to 300 keV with electrostatic scanning of ions
7	1st output magnetodynamic 2 or 4 cycle chamber with 2 injectors	Synthesis of ^{7}Li with ^{1}H
8	Magnetooptic storage device-limiter	Holds up charged ions
9	2nd output magnetodynamic 2 or 4 cycle chamber with 2 injectors	Synthesis of ^{14}N and n
	^{14}C divertson system	

Figure: Nodes of the Generator.

Composition of plasma electric generator

- Vacuum cylindrical cartridge-vaporizer with lithium hydride
- Electron-gun ion source
- Plasma source of lithium and hydrogen ions
- Section of magneto-optical storage of lithium and hydrogen ions
- Lithium and hydrogen ion accelerator section
- Section synthesis of lithium ions and hydrogen eight-cyclic
- Quantum energy device (Flight RF device) at a frequency of up to 1 MHz
- Section a magneto-optical drive camera ion neutralizer
- The camera section of the ion neutralizer gun electronic
- Air cooling system with heat exchanger
- Electronic generator control system
- The base and the housing of the generator

MOS & MQL

Magnetodynamic N-cyclic camera synthesis consists of MOS magneto-optic systems – synthesis performed according to the scheme of combination of magnetic quadrupole lenses (MQL), providing a "strong" focus compression method discrete ion beams of hyperbolic fields separated by a magneto-optical system shapers-limiters, performing the function of locking or crossing a discrete flow. Effective length $L_{eff} = \frac{1}{G_0} \int\limits_{-\infty}^{+\infty} G(z)dz$. The field in the aperture of quadrupole lenses satisfies Maxwell's static equations: $\mathrm{rot}\vec{B} = 0$, $\mathrm{div}\vec{B} = 0$, static magnetic field potential $\vec{B} = \mathrm{grad}U_0$, satisfying the Laplace equation in cylindrical coordinates, the General solution of which is written as $U(r, \varphi) = \sum\limits_{n=1}^{\infty} r(a_n \sin(n\varphi) + b_n \sin(n\varphi))$. The initial parameters for the design calculation of a quadrupole lens determine the gradient of the focusing field, the distance from the lens axis to the pole and the number of ampere turns required to create a field with a given gradient, which is determined from the Maxwell integral equation: $\int\limits_{\Gamma} \vec{H}d\vec{l} = \int\limits_{S} \vec{j}d\vec{S}$. Calculating we obtain $\frac{Ga^2}{\mu_0} = 2NI$, where NI – number of ampere turns, G –field gradient. The value of the transverse field gradient, which is related to the value of the current of the supply coils of the poles and B_p magnetic induction at the pole $G = \frac{B_p}{r_a}$. Here μ_0 is magnetic constant, NI – number of ampere-turns in the exciting coil of the pole, k – coefficient, what takes into account the physical properties of the material poles and yoke of the magnetic quadrupole lens; r_a – the radius of the lens aperture.

Offer to the attention of the development relies on the method of obtaining the controlled streams of ions or plasma, the realized magneto-optical shaper-drive, forming and modulatory accelerators for the formation of linear streams of plasma concentration required and the period of engagement. The technology of electronically controlled plasma synthesis of generators is a new method of obtaining the controlled streams of ions to obtain linear flow of ions or electrons selectable flow. That is, setting the laws of change of parameters (energy E, particle current I, concentration n, period T_{sl} allows to form primary electronically controlled flows of charged particles-ions and electrons. The most common functional discretization in which the ion current, j_i, n_i concentration, energy flow E_i interconnected and change according to a certain law specified as a single function of sampling rate, $F(I_i, n_i, E_i)$.

The obtained discrete flows of ions and electrons formed by a group of particles with the same velocities and coordinates and concentrated in a small region of phase space forming clots or discrete. In the synthesis generator motion occurs in a magnetic solenoidal and quadrupole magnetic lenses ML.

In the electromagnetic field, the motion of the discrete is given by the Newton-Lorentz equation ($v = \frac{dR}{dt}$):

$$\frac{dmv}{dt} = q(E + [v \times B]), \tag{1}$$

where R - radius-vector of the observed particle in the laboratory coordinate system; m, q - particle mass and charge; v - velocity; E - vector of electric field intensity; B - magnetic induction vector. Then for a two-component flow 1 can write so ($v_{ij} = \frac{dR}{dt}$):

$$\frac{dmv_{ij}}{dt} = q(E + [v_{ij} \times B]) \tag{2}$$

The movement of the discretes has the complex spatial nature, but if the speed lies in the symmetry plane, the motion is discrete to be flat. Quadrupole lenses are referred to as transverse lenses whose magnetic fields have a stronger effect on the movement of particles compared to longitudinal. For a discrete moving in the quadrupole lens in the plane $y = 0$ the force $F_x = ev_zB_y$ acts, where e - particle charge, v_z - the longitudinal velocity of the particle is equal to the value of the total velocity at $y = 0$.

The equation of motion for discrete flows moving rectilinearly with respect to the MQL axis:

$$\frac{dQ}{dz} = f(B(x, y, z), x^{'}, y^{'}, \delta), \qquad (3)$$

where $Q(x, y, x^{'}, y^{'})^T$ - vector of trajectory phase coordinates of the particle, $\delta = \frac{\Delta p}{p_0}$ - the distribution of particle momentum; $B(x, y, z)$ - distribution of the magnetic induction vector along the MQL axis.

Since these equations of motion are nonlinear with respect to the phase coordinates, it is possible to find an approximate solution by moving from the trajectory phase space to the space of the trajectory phase moments for discrete flows moving rectilinearly with respect to the MQL axis.

$Q(x, y, x^{'}, y^{'})^T \rightarrow Q^*(x, y, x^{'}, y^{'})^T$, whrere Q^* - vector of trajectory phase coordinates of the particle. Then the equation of motion is written as:

$$\frac{dQ^*(z)}{dz} = P(z)Q^*(z), \;\; Q^*(z_0) = Q_0^*, \qquad (4)$$

where $P(z)$ - he square matrix which is determined from the axial distribution of the magnetic field MQL; Q^* - trajectory phase moments of the third order.

For a more rational solution we need to find the matrix function we need to find the matrix function $K(\frac{z}{z_0})$. Transformation of the coordinates of the trajectory phase moments of each discret on the plane perpendicular to the axis with the coordinate z_0 at the entrance to the MQL in the plane $z_1 \geq z$, where z_1 is the plane at the output. Then can be write:

$$\frac{dK(\frac{z}{z_0})}{dz} = P(z)K(\frac{z}{z_0}), \;\; K(\frac{z}{z_0}) = \mathbf{E}, \tag{5}$$

where **E** - identity matrix. For each MQL, and their synthesis generator from 4 to 16, in our case 8, knowing the matrix transformation function can describe the dynamics of motion of the discrete throughout the synthesis chamber by a series of matrix transformations of the coordinates of its trajectory phase moments.

By setting each thread a time interval τ_{ij} termines the parameter sequence (k_i, k_j of each discrete D. For each τ_{ij} rresponds to a set of values U_{ij}, I_{ij}, discrete flow zij. U_{ij} - matrix of values of the accelerating voltage of the accelerator-driver and I_{ij} - matrix of values of the electric current of the accelerator-generator. Generally U_{ij}, I_{ij}sponds to P_{ij} - matrix of values of electric power for a given accelerating voltage of the accelerator-driver.
Then for the formation of a multiphase flow will take place:

$$F_i(D) = \sin \omega t + \phi_i, F_i(D) = \sin \omega t + \phi_n, F_j(D) = \cos \omega t + \phi_i, F_j(D) = \cos \omega t + \phi_n \quad (6)$$

where $F_i(D)$ - function of i-component, $F_j(D)$ - function of j-component, ω - repetition frequency discretes, ϕ_i, ϕ_n - phase discrete flow.
One of the embodiments of a method of forming a discrete trajectory streams with different phase values substantially rectilinearly relative to the axis of MQL is quadrature sweep along the axes x,y in the output accelerator-modulator. The MOS scan DAC is supplied with a deflecting voltage functionally with the given values, which allows forming at the entrance distributed in the space of discrete multiphase flows.

Estimated parameters of the neutron generator

- neutrons yield up to 10^{15} neutrons/s; (E_n=14 MeV)
- duration of radiation pulses from 0.01 μs to 10 ms;
- pulse repetition rates from single to 10 kHz;
- time-constant neutron flow;
- service life, h (at a flux of 10^{14} neutrons/s) 24 000 h.

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Energy parameters thermonuclear fusion

Reaction	Energy, MeV	σ_{max}, b (in the energy region $\leq$ 1 MeV)	Energy of the impinging particle, MeV
1) $p+^6Li \rightarrow ^4He + ^3He$	4.0	10^{-4}	0.3
2) $p+^7Li \rightarrow ^2 4He+$	17.3	$6 * 10^{-3}$	0.44
3) $d+^6Li \rightarrow ^7Li + p$	5.0	0.001	1.0
4) $d+^6Li \rightarrow 2^4He$	22.4	0.026	0.60
5) $d+^7Li \rightarrow 2^4He + n$	15.0	10^{-3}	0.2
6) $p+^9Be \rightarrow 2^4He + d$	0.56	0.46	0.33
7) $p+^9Be \rightarrow ^6Li + ^4He$	2.1	0.35	0.33
8) $p+^1 1B \rightarrow 3^4He$	8.7	0.6	0.675
9) $p+^1 5N \rightarrow ^1 2C + ^4He$	5.0	0.69 (at 1.2 MeV)	1.2

The minimum energy of the incident flow must be at least the threshold energy for the reaction $p +^7 Li \rightarrow^2 4He+$ is 0.44 MeV at an energy output of 17.3 MeV. In our case, the energy of the target and the energy of the incoming flow are equal. By specifying the number of ions N_{Li}, N_H and taking $N_{Li} = N_H$. Find the energy required for a given number of ions. Given that in 8 grams of LiH contains $6.022140857 * 10^{23}$ will receive.

My price table

number	Number of moles LiH	Number of atoms	Ion current, A	E_{syn}, J	E_{out}, J
1	$4.516 * 10^{15}$	$7.25 * 10^{-4}$	$6.0 * 10^{-11}$	637	12500
2	$9.033 * 10^{15}$	$1.45 * 10^{-3}$	$1.2 * 10^{-10}$	1274	25000
3	$1.8066 * 10^{16}$	$2.9 * 10^{-3}$	$2.4 * 10^{-10}$	2548	50000
4	$3.613 * 10^{16}$	$5.8 * 10^{-3}$	$4.8 * 10^{-10}$	5096	100000
5	$7.226 * 10^{16}$	$11.6 * 10^{-3}$	$9.6 * 10^{-10}$	10190	200000

Possible application. Carbon-14

1. The production of C-14 in the dense ion plasma flow is much cheaper than the production of Ni-63 in Nickel target, due to the low cost of N-14.
2. Ion-plasma implantation C-14 on SiC substrate allows to reduce the crystal process and realize wide production on semiconductor converters on C-14.
3. At the same time, the production of Ni-63 by this technology is also possible, and the cost will be much reduced compared to traditional methods. Because of the greater mass of the ions, the equipment for ion-plasma sputtering with a seal of the flow of Nickel ions will be several times more expensive because of increased working installation area. At this stage, it is more sophisticated to produce C-14.
4. Specific activity of C-14 is different from the Ni-63 about in 10 times per unit volume, due to the huge difference in half-life times.
5. Self-absorption of Ni-63 is larger by approximately three times, which leads to the maximum limit optimal thickness of the layer to 4 microns, and for C-14 this thickness may be up to 60 microns which is better suited. The total quantity of the isotope C-14 may be an order of magnitude greater, therefore, guaranteed more power for the same size of power converters.
6. The specific power of Ni-63 per gram of the substance 5 times (due to more activity) exceeds the power density of C -14. But the maximum and average energies of electrons in the C-14 decay is in 2, and even 3, times more than in the Ni-63 decay.
7. The production cost of 12 *m*g C-14 will take approximately 8 hours, taking into account equipment depreciation, will cost about 170$.

Thank you for attention!