HIGH-CURRENT PULSING DEUTERON ACCELERATOR WITH ENERGY OF 500 KeV

K.I. Kozlovskij, E.D. Vovchenko, A.A. Isaev, M.I. Lisovskij, A.E. Shikanov, National Research Nuclear University "MEPhI" (Moscow Engineering Physics Institute), Moscow, Russia

Abstract

In this work it is reported about development of compact prototype of fast ions and deuterons accelerator with next parameters: energy is up to 400 keV, electric current is more than 1 kA and current density is more than 20 A/sm^2 in pulses with duration up to 0,5 µs and repetition frequency is equal to 1 Hz. Method of electron magnetic insulation in accelerating gap was applied and optimized in the accelerator; intensive laser-plasma ion source was used.

INTRODUCTION

Researches in the area of magnetic insulation applied to compact diode systems for neutrons generation initially are introduced in the work [1]. Two possible schemes of electronic conductivity dampening exist. In the first case, the field of constant magnets with azimuthal symmetry is used [2,3]. In the second case pulsing helix magnetic field is applied [2,4]. However, it is experimentally established, that electronic conductivity dampening by the field of constant magnets [3] has a series of significant shortcomings. These shortcomings are connected with complex configuration of magnetic field and its inhomogeneity.

It was established by authors, that similar shortcomings to a lesser extent appears in diodes with pulsing magnetic insulation. In this work results of experimental investigation of similar diodes were set out.

EXPERIMENT

For the plasma production, YAG laser, activated by neodymium, generating pulses of infrared rays in modular Q mode with wave length of 1.06 µm, energy ≤ 0.85 J and duration is about 10 ns. was used.

Magnetic field in the diode configured with the help of helix, which forming surface had a frustaconical shape. Critical distinction between this experiment and experiment, conducted earlier is in the use of more powerful laser, high-stable PVG with characteristics, mentioned above and original scheme of start on the basis of laser controllable arrester (LCA).

An important aspect is the use of high-voltage pulse generator according to the scheme of Arkadyev-Marx, generating at idling conditions with amplitude of 400 kV and first half wave duration of 1 µs, in which original scheme of its start, based on LCA, is applied.

A laser target in the form of a tablet made of TiD was placed on the anode. Deuterons are extracted from the laser plasma in an electric field formed by a positive high-voltage pulse on the anode.

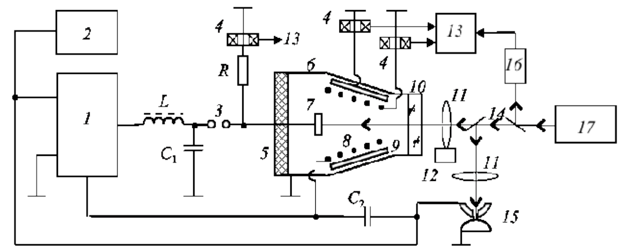

Figure 1: Scheme of experiment “Formation of deuteron flux”: 1 – PVG (2–30 cascades); 2 – PVG charging unit; 3 – arrester-peaker; 4 – Rogowski coils; 5 – insulator; 6 – vacuum chamber; 7 – plasma forming target; 8 – helix; 9 – ion collector (cathode); 10 – optical window; 11 – focusing lens; 12 – scanning device; 13 – oscillograph; 14 – partially transparent mirror; 15 – LCA; 16 – Photoelectronic coaxial converter PCC; 17 – laser.

We applied a pulsed magnetic isolation for suppression of parasitic electron current due to secondary electron emission at the cathode. Conical spiral is placed in the diode gap in front of the cathode, which also had a conical shape (Fig. 1). In addition, conical surface of the cathode and conical spiral are parallel. Diode system placed in a vacuum chamber pumped to a pressure of 10^{-2} Pa.

A laser plasma emission is accompanied by its expansion in the radial direction. The flow of deuterons reaches the conical spiral with a delay $\tau_P \approx 250 - 300$ ns.

Estimation of the efficiency of generating the magnetic field showed that current in the conical spiral achieved 60% from its maximum value after 300 ns from the beginning of the expansion of a laser plasma (i.e. when the flow of deuterons reaches the conical spiral).

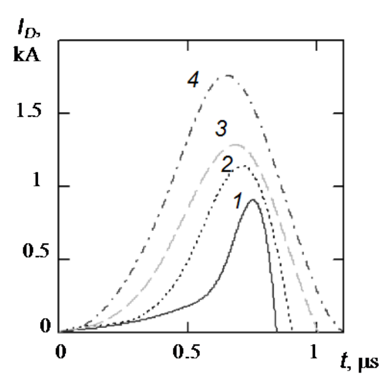

Figure 2: Diode current $I_D(t)$ at laser energies: *1* – 80 mJ, *2* – 200 mJ, *3* – 380 mJ, *4* – 750 mJ.

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Accelerated deuterons current and current in helix circuit were measured by oscillograph with the help of Rogowski coils. On the Fig. 2 pulses of deuteron current at various energies of laser radiation are presented. They were obtained in the result of experimental oscillogram processing using method of cubical interpolation. It is needed for theoretical analysis of possible neutron yield. Obtained experimental data allows us to evaluate perspectives of neutron generation in considered diode system. Neutron yield per pulse is determined by equation:

$$Q(W) \approx \frac{n}{e}\int_0^{\tau} dt \cdot I_D(W,t) \int_0^{eU(t)} dE \frac{\sigma(E)}{F(E)},$$

where is n – concentration of reagent nuclei in the plasma forming target, e – elementary electric charge, τ – pulse duration of deuteron current, $U(t)$ – time dependence of accelerating-voltage, $F(E)$ – Deuteron energy loss per unit target length, $\sigma(E)$ – micro-cross section of nuclear reaction.

Dependences of deuteron current and electric potential on time were taken from oscillograms, obtained from the results of experiment. Evaluations of neutron yield were obtained for following nuclear reactions $T(d,n)^4He$ and $D(d,n)^3He$, usually used in compact neutron generators. Calculation results of neutron yield are shown in Table 1.

Table 1. Calculation Results – *Q(W)* Neutrons/Pulse

W, mJ	Nuclear reaction	
	$T(d,n)^4He$	$D(d,n)^3He$
80	$2 \cdot 10^{10}$	$1.5 \cdot 10^8$
200	$4 \cdot 10^{10}$	$3 \cdot 10^8$
380	$6 \cdot 10^{10}$	$4 \cdot 10^8$
750	$8 \cdot 10^{10}$	$6 \cdot 10^8$

CONCLUSION

Experimental investigation of diode for neutron generation with laser-plasma deuteron source and pulsing magnetic insulation by helix of conical shape at laser pulse energy and amplitude of accelerating-voltage correspondingly equal to $W = 0.75$ J and $U_0 = 300$ kV was carried out.

It was shown, that within stated limits of W and U_0 proportion between amplitude of deuteron current and laser pulse energy is held.

Calculations for given ranges of W and U_0 showed that the neutron yield to full solid angle when using nuclear reaction $T(d,n)^4He$ could reach 10^{11} neutrons/pulse.

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