COLLECTIVE ION ACCELERATION IN THE VACUUM
SYSTEM WITH INSULATED ANODE:

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Summary. Experiments are described of ion acceleration in diode with insulated anode mounted on two E-beam generators that deliver 2 kJ and 1 kJ of energy in 1 MeV, 50 ns and 0.35 MeV, 80 ns pulses accordingly. The maximum yield of protons $10^{14} - 10^{13}$ with energy in $(1.9 + 2.7)$ MeV range were measured with accompanying $20 \text{ ns}$ pulses accordingly. The maximum yield of neutrons in the reaction $7 \text{ Li}(p, n)\text{Be}$ was $N = 1.2 \times 10^9$. This amount corresponded to $(E_i/E_e)_{\text{max}} = 14$. Reproducibility and effectiveness of acceleration processes were investigated.

Introduction. Besides well known methods of the ion acceleration in relativistic electron beams drifting in neutral gases, new approaches of ion acceleration are in progress now at several laboratories. The simplicity of applied technique and rapid successes in attaining high ion yields and energies stimulate further investigations in these directions.

Experimental. We have carried some experiments on collective ion acceleration on the device similar to one proposed in $^2$ using two E-beam machines that delivers 2 kJ and 1 kJ of energy in 1 MeV, 50 ns and 0.35 MeV, 80 ns pulses. Our generators differed from those used in mentioned above works by long pulse rise time (40 ns) and absence of prepulse switch, suppressing the microsecond duration pulse during the charging phase. To investigate the influence of these factors on effectiveness of acceleration processes a lot of experiments were fulfilled on modified accelerator guns, in which suppression of prepulse and some shortening of current rise time were attained by insertion insulators-caprolon pieces ($L = 5 \text{ cm}$) between the needle tungsten cathode and shank. In first experimental run the electron beam from 2 mm in diameter tungsten needle was injected through the central hole in the insulated anode (fabricated from polyethylene, caprolon, teflon and plexiglass) in the vacuum chamber 500 mm in diameter and 300 mm in length and impinged on the target grounded through the resistor of the Faraday cup (F.c.) or directly. The measurements of ion-electron beam intensity, electron range in some experiments on copper foil targets gave the average value $800 \text{ keV}$ for 2 kJ machine and $330 \text{ keV}$ for 1 kJ one.

Results. Briefly the main results are following:

1. In the system anode-grounded target the electron-ion beam was drifting over the distance up to 300 mm with spreading $\sim 2^\circ$. This fact witnessed about high degree of charge neutralisation ($2 + 3 \times 10^3 < f < 1$).

2. In the experiments carried on 2 kJ machine without an insulator piece between the cathode and shank the maximum energy of accelerated ions did not attain the energy of experimentally established threshold of $\text{Cu}^{+2}(p,n)\text{Zn}^{63}$ reaction, the maximum yield of neutrons in the reaction $\text{Li}^+(p,n)\text{Be}$ was $N = 1.2 \times 10^9$. This amount cor-

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Fig. 1 The scheme of experimental setup with electrodes assembly mounted on 1 kJ machine.

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responds to the proton number \( N_p = 10^{12} \pm 3 \times 10^{13} \) in the region (1.9 ± 2.7') MeV.

The typical pulses from E.c. with central hole in it for TP measurements, diode voltage divider, X-ray detector and TOF probes are presented on fig. 2. From the shape of TOF-probes signals we conclude that protons were accelerated in several bunches during 30 ns. The amplitude of ion current in bunches attained 4.0 kA accompanied by 18 kA of electron current.

Using data of TOF method and range-spectrometer measurements on 1 kJ machine we calculated the moments of the beginning of ions acceleration. On fig. 3 the values of these moments are given for several \( E_i/E_e \).

These results are consistent with E.c. data. In these experiments we investigated the \( E_i/E_e \) dependence versus anode-rear target distance (see fig. 4).

3. Suppression of charging prepulse on 2 kJ machine and shortening of the current rise time due to insertion of insulator piece in the cathode resulted in increased proton energy up to 5 MeV with the maximum neutron yield in the reactions

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\text{Cu}^{63,65}(p,n)\text{Cu}^{64,66}\quad N_p = 1.5 \times 10^8
\]

which corresponds to total proton number \( N_p = 10^{13} \pm 3 \times 10^{13} \) MeV. These values are consistent with the data from range-spectrometer and TOF measurements.

4. Insertion of several post-anode electrodes (from one to three) with alternative or all grounded on 1 kJ E-beam generator resulted in increased energy up to 4.2 MeV (see fig. 5).

The reproducibility was poor and the total proton and neutron yields varied from shot to shot up to two orders. As a rule the highest neutron yield were detected in the shots with negligible degree of anode des-
traction and best reproducibility — when using the caprolon as anode’s material, it was suggested that further development of this simple and effective method of ion acceleration depend upon solving the problem of active control over insulator surface breakdown. We are now preparing experiments in which anode-dielectric breakdown is controlled by the closure of pressurised gas switch inserted between the anode and grounded vessel.

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