Plasma parameters investigation for heterogeneous low-density load on high current generator

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The goal of this work was to investigate plasma parameters for heterogeneous low-density load on high current generator Angara 5-1. The load consisted of two agar-agar columns and CD₂ neck between them. Low density load containing deuterium atoms are the most suitable for modeling fusion experiments for ICF purposes. The experiments were carried out on Angara-5-1 device (currents up to 3.5 MA with 120 ns increasing time).

Experiments with currents 1.5-2 MA have shown that the most suitable substance for a load is microporous deuterated polyethylene with small density (50-100 mg/cm³) [1]. Use composite profiled load which central part produced from microporous deuterated polyethylene [2], has allowed to transmit effectively energy from generator to a target.

The central part of load was produced from microporous deuterated polyethylene with density of 100 mg/sm³ and diameter (1-1.3) mm. Spatial-time Z-pinch parameters were studied by

Fig.1 Target unit of Angara 5-1.
frame photography in soft x-ray spectral region with 5 ns exposure and optical streak camera with 2 ns time resolution. The structure of high-temperature plasma in soft x-ray range was registered using time integrated three pinhole cameras with apertures of 50 mkm with different filters. Vacuum photoemission detectors were used for measuring x-ray radiation intensity. Also VUV and X-ray spectroscopy methods were used to estimate plasma parameters. Neutrons energy was measured by a time of flight method, for measuring of total neutron yield from the load neck the activation detector was used.

The neck luminance observed by streak-camera in visible range (slit is parallel to the load axis) began from about 30 ns. Diameter of neck was equal ≈ 1 mm during ~100 ns. Maximal plasma compression attending x-ray and neutron emission was observed on the current front (about 90 ns after the current beginning). Soft x-ray pulses with energy E > 0.8 keV had 3-4 ns duration.

From t≈110 ns plasma expansion in radial direction with v~4×10^6 cm/s was observed. On streak-camera photography with slit installed parallel to the load axis bright plasma formations was observed with a size of ~100 μm and 4-8 ns duration were observed near t

Fig.2 (a) Current and soft x-ray signals; (b) streak-camera imagine (slit is perpendicular to the load axis), (c) streak-camera imagine (slit is parallel to the load axis).
≈120 ns.
In the same time plasma formations illuminating in soft x-ray range appeared in the load neck. Size of hot spots, registered by time integrated pinhole cameras was 200-300 microns for E > 0.6 keV energy region.

![Fig.3 Time-integrated pin-hole camera imagines with different filters.](image)

Also the plasma VUV spectra were registered by grazing incidence spectrograph. Lines if FeXVI – FeXVIII were observed. Electron temperature estimation made by method suggested in [3] ($\lambda_{\text{max}} = 60$ Å) gave $T_e \sim 300$ eV.

![Fig.4 EUV plasma spectrum. Red lines correspond to the photometric measurements area.](image)

The neutron yield depended on a load configuration. The maximal neutron yield was observed
in case of decreasing neck length and using the composite load with copper conical columns and achieved about 3x10^{10}. Average neutron energy measured by time of flight method in the radial direction (at angles 90° to a load axis) was close to 2.5 MeV.

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References
1. J.L. Merkulev et. al., pre-print of P.N. Lebedev Physical Institute Russian Academy of Science, 44(2005).