Laboratory Simulations of Astrophysical Jets: Results from Experiments in the PF-3, PF-1000, and KPF-4 facilities

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Laboratory simulation of astrophysical jets is a rapidly developing field of research. Plasma focus devices are well suited to simulate jets from young stellar objects. At present, extensive international efforts are devoted to studies with the three world's largest plasma focus devices: PF-3 (NRC Kurchatov Institute, Moscow), PF-1000 (IPPLM, Warsaw) and KPF-4 “Phoenix” (SFTI, Sukhum).

In the PF-3 facility, experiments were performed at the stationary gas filling of the discharge chamber. The regimes with formation of a narrow collimated plasma jet were obtained. The head of this jet was no wider than several centimeters at jet propagation distances up to 100 cm. In neon and helium discharges, the parameters of the plasma jet and background plasma were determined at different distances from the pinch column. Magnetic field structures which were produced by return currents were observed at the jet periphery. Although the magnetic field was strongly damped as the jet propagated along the chamber, the head of the jet remained well collimated, presumably because of the radiative cooling of plasma.

Experiments performed in the PF-1000U and KPF-4 facilities were aimed mainly at the formation of profiled initial gas distributions in order to control the conditions of the propagation of a plasma jet through the background plasma. The PF-1000U device, which could be operated with an additional injection of the working gas into the axial region of the discharge, generated compact plasma objects with dimensions up to several centimeters in diameter, at a distance of 40 cm from the anode outlet, and the jet configuration depended on the gas injection. The axial currents, which could flow within those objects and produce a toroidal magnetic field, were closed through the jet periphery. The plasma density at a distance of 57 cm from the anode end was estimated from an analysis of the Stark line-broadening and was found to vary in the range of (0.4 – 3.7) × 1017 cm−3. It depended on the initial gas distribution and the time delay between the spectrum recording and the instant of the plasma jet generation. The estimated electron temperature was about 5 eV, and the density of the background plasma was found to be about 1.5 × 1015сm−3.

In experiments performed in the KPF-4 device, the magnetic field distribution in the plasma jet was determined by comparing the data from magnetic probe measurements and images recorded by the streak-camera in the visible range. It was shown that the magnetic field was trapped by the plasma jet in small regions (so-called magnetic bubbles) weakly emitting in the optical range. In the KPF-4 device, another regime with pulsed gas-puff, which differed from that used in PF-1000, was investigated, namely, that forming an increased density near the insulator surface. The jet velocity in this regime was shown to remain nearly constant during the jet propagation and to increase as the gas pressure at the discharge axis in the anode-cathode gap increased.

The work was supported in part by RFBR (projects 14-29-06085-OFI\_M, 14-02-01203-a, 14-02-00179-a, 15-52-40009 Abkh\_a, and by the research program under grants IAEA RC-16115, RC-19253 and RC-17088.