Testing of a Plasmadynamic Hypervelocity Dust Accelerator

Cătălin M. Ticos, Zhehui Wang, Leonid A. Dorf, Glen A. Wurden

LA-UR-06-7662 MFE Team, Plasma Physics Group P-24

Los Alamos NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY NNSA

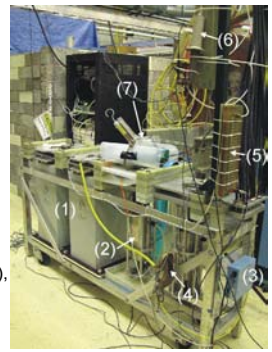
ABSTRACT

A plasmadynamic accelerator for microparticles (or dust grains) has been built and tested at Los Alamos National laboratory. The dust grains are expected to be accelerated to hypervelocities on the order of 1-30 km/s, depending on their size. The key components of the plasmadynamic accelerator are a coaxial plasma gun operated at 10 kV, a dust dispenser activated by a piezoelectric transducer, and power and remote-control systems. The coaxial plasma gun produces a high density (~10^{16}-10^{18} cm^{-3}) and low temperature (~1 eV) plasma in deuterium ejected by **JxB** forces, which provides drag on the dust particles in its path. Carbon (graphite) dust particles are used, with diameters from 1 to 50 μm. The plasma parameters produced in the coaxial gun are presented. The speed of dust is deduced from time of flight measurements. Hypervelocity dust will be injected in the National Spherical Torus Experiment to measure the pitch angle of magnetic field lines. This work is supported by DOE Contract No. W-7405-ENG-36 through the Office of Science, Office of Fusion Energy Science.

POWER SYSTEM

Design parameters:
- discharge voltage: up to 10 kV
- 1 mF capacitor bank, up to 50 kJ
- discharge current: ~100-250 kA
discharge duration ~50-300 μs

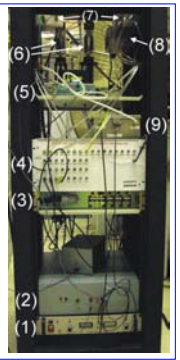
Components:
•Capacitor bank (1), ignitron (2), ignitron driver (3), hard dump (4), voltage divider (5), Tektronix HV probe (6), Pearson current probe (7).



CONTROLS

•Real-time LabVIEW software with linked Field-Point modules (Analog/Digital In/Out)
•Compressed air for switching the charging/dumping relays
•Interlocks embedded for safety and protection

Components:
•12 kV Glassman HV source(1), puff gas driver (2), power breaker (3), LabVIEW Field Points (4), interlocks (5), Jennings switches (6), compressed air switches (7), 24 VDC relays (8), electrical/optical converters (9).



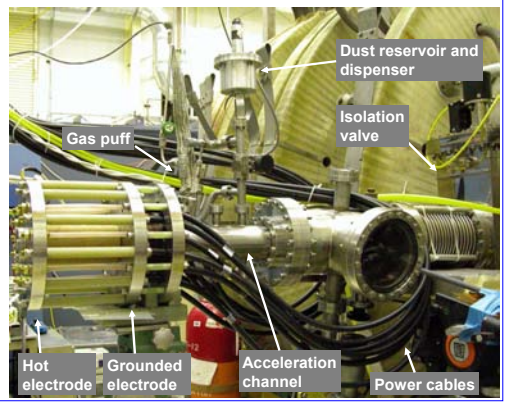
COAXIAL PLASMA GUN FOR DUST ACCELERATION

•A plasma produced in deuterium between 2 coaxial electrodes and ejected by the **JxB** force is used to accelerate dust grains at speeds of up to 30 km/s.

•Carbon dust grains with sizes 1-50 μm have been used.

•Coaxial gun dimensions: center electrode has Ø=1.9 cm, L=20 cm, and coaxial electrode has inner Ø=3.2 cm, and L=20 cm.

•Puff gas valve with orifice Ø=0.8 mm, and ~1 ms opening time; dust dispenser with piezo-shaker activated remotely.

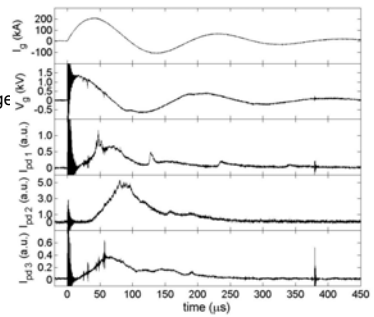


GUN PERFORMANCE

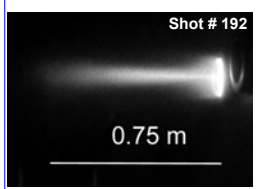
Typical shot (# 266):

•V_{bank}=8 kV, Vg and Ig are instantaneous gun voltage and current; the ignitron closes the circuit at t=0
•I_{gmax}=210 kA after 40 μs

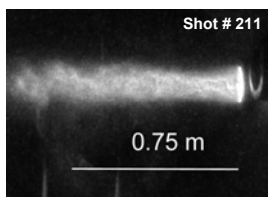
•Photodiodes with side-view mounted at the gun exit (Ipd1), and at 0.9 m downstream from the gun muzzle (Ipd2), and with end-view (Ipd3) which looks into the coaxial gap
•Plasma flow speed ≥ 28 km/s (~33 μs between the peaks of Ipd1 and Ipd2)



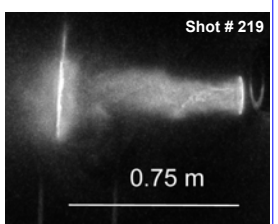
IMAGES OF EJECTED PLASMA FLOWS



V_{bank}=5 kV, 30 μs exposure, 4 ms puff gas (~1.76 torr L/ms for a plenum with 150 psi)



V_{bank}=8 kV, 2 exposures of 0.5 μs each, separated by 40 μs, 4 ms puff gas



V_{bank}=5 kV, same exposures and puff gas as in #211. The plasma hits a target plate (dust collector)

DETECTION OF HYPERVELOCITY DUST

•Glowing dust imaged by a high speed camera • with a telephoto lens 500 mm f/4 before hitting a target plate (dust collector) at 1.5 m from the gun muzzle.

•From time-of-flight the dust speed is ~2.3 km/s (exposure 10 μs).

Image of 3 dust grains, each with a speed of ~1.1 km/s, for an exposure of 5 μs.

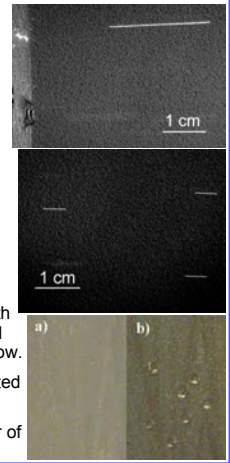
•The calibration is done by imaging a ruler ahead of the experiment.

•The resolution is found to be 190 pixels/cm.

•The dust collector is a Teflon sheet covered with high-vacuum grease (a) and mounted on a steel plate which is placed downstream the plasma flow.

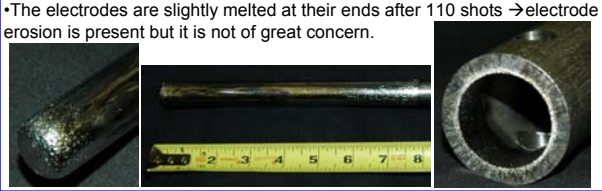
•After 10 shots a thin layer of graphite is deposited onto the sheet (b).

•Craters with sizes of 10-100 times the diameter of the hypervelocity dust are observed (b).



OTHER ISSUES

•The electrodes are slightly melted at their ends after 110 shots →electrode erosion is present but it is not of great concern.



SUMMARY

•A plasmadynamic hypervelocity dust accelerator has been tested at LANL

•Images taken for different values of the bank voltage show a well collimated plasma flow over a distance of 1.5 m from the gun muzzle.

•Glowing dust grains with speeds between 1 and 2.3 km/s have been detected downstream the plasma flow with a high-speed camera and a telephoto lens.

•A systematic scan of dust speeds for different plasma parameters and puff gas times is currently ongoing.

•In order to restrict the plasma flow from entering NSTX several methods are being analyzed: an aperture placed in the path of the plasma flow, or the use of a surge tank.

•Mechanical and electrical interfaces are being developed in order to facilitate the installation of the hypervelocity dust injector (HDI) on NSTX.