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TITLE: DIAGNOSTICS OF A HIGH CURRENT CAPILLARY DISCHARGE

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DIAGNOSTICS OF A HIGH CURRENT CAPILLARY DISCHARGE

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INTRODUCTION

We have started to investigate the hot dense plasmas formed by passing a large current ($I > 100$ kA) through small diameter (10-25 μm) large aspect ratio capillaries (length/diameter >> 1) in insulating materials. The initial interest in such a device as a plasma source was provided by McCorkle.[1] In this paper, we will discuss 1) several theories which may provide a description of the operation of this device, 2) the experimental design (power source, capillaries, and diagnostics), and 3) the results of our preliminary experiments. These preliminary experiments have demonstrated that we can drive large currents ($I > 10^5$ A) through small diameter capillaries ($d \approx 10$ μm) and generate a plasma that produces x-rays with energies greater than 1 keV.

THEORY

Several different models may be used to describe a discharge in a very small diameter capillary. We will briefly mention three models that may be applicable. Although it is not clear at this time which model best describes the present experiments, it is evident that to maximize the temperature generated in the plasma, one should select small diameter capillaries. In the first model the capillary discharge may be described as a scaled down version of the classic Z-pinch where a plasma is generated along the walls of the capillary and imploded by the Lorentz force. The Z-pinch model implies a decoupling of the ablated wall material which forms a plasma on axis from the capillary wall. To minimize the amount of material heated and to maximize the magnetic field, a small diameter capillary should be used. A second model by McCorkle[1] proposes that in a small diameter capillary one can use the intense power flux impinging upon the walls of the capillary to decouple the interior (blow off) plasma from the walls of the capillary. The key is to keep the area (diameter) of the capillary small so that the wall loading is large to minimize the thermal

coupling. Finally, one may extrapolate the work of Jones, et. al[2] on laser initiated Z-pinches in gases to the solid density regime. In this model the current carrying plasma column expands into the surrounding media. Again to limit the material accreted one should select small diameter capillaries to minimize the mass to be heated.

EXPERIMENT

Capillaries must be formed in an insulating material. The geometry of the insulator must preclude the current from following paths other than through the capillary. The configuration for the insulator is shown in Fig. 1. The cathode is pointed to enhance the electric field in the region of the capillary. The cathode point and anode protrusion make the system self aligning to the axis of the machine and the diagnostics. The capillary is isolated by "O-ring" seals from the rest of the chamber.

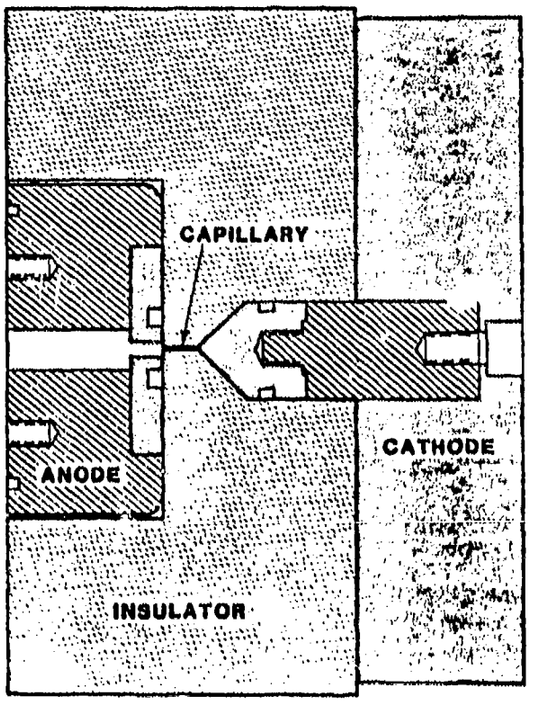

Fig. 1. The insulator configuration used in the present experiments. The pointed cathode provides field enhancement to guide the discharge down the capillary. The region outside the insulator is filled with SF_6 to improve the voltage hold off characteristics of the insulator.

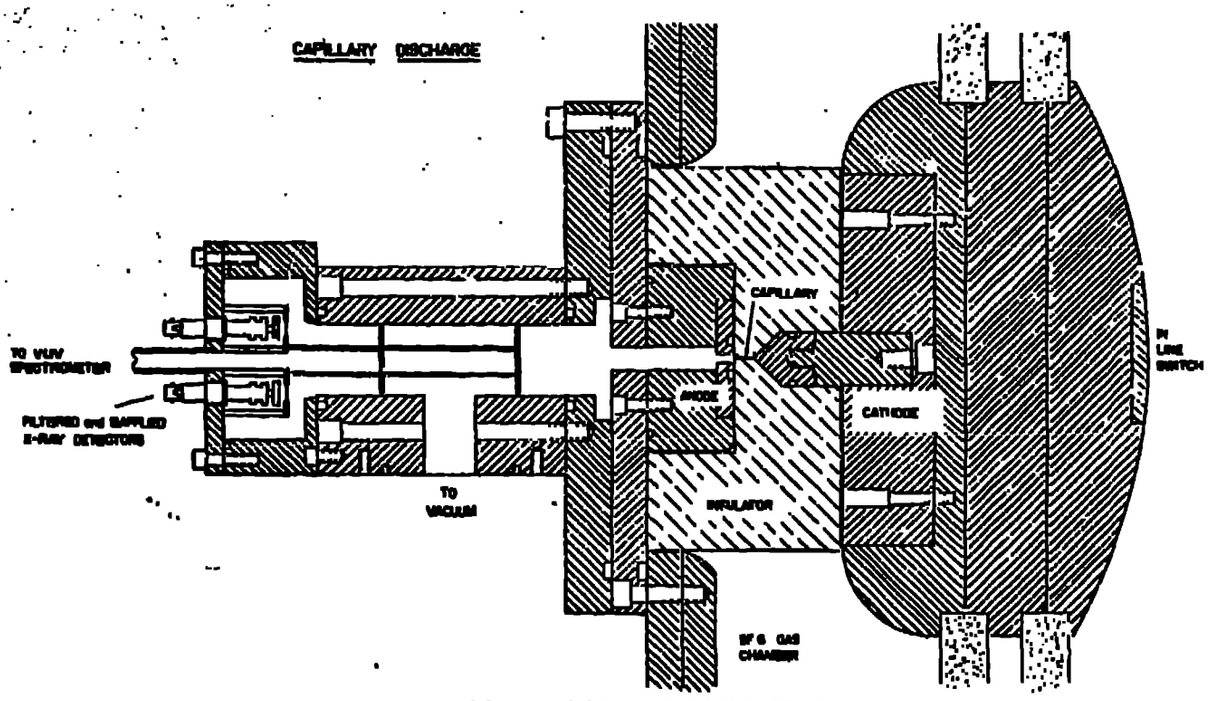

Fig. 2. The load end of the experiments including the diagnostics and insulator.

PRELIMINARY RESULTS

In our first experiment we demonstrated that we could successfully flow 260 kA in 200 ns through a polyethylene capillary (25 μm initial diameter). No x-ray data was obtained on this shot. We subsequently tested a 10 μm polyethylene capillary. The current peaked at 135 kA and was limited by a breakdown in a section of the in-line switch. Agreement was obtained between the current delivered to the load and to the chamber, i.e., all the measured current flowed through the capillary (see Fig. 3).

Figure 4 shows the x-ray data obtained on this shot. The signals from the open and 65 μg/cm^2 formvar channels rose quickly off scale when the current initiated while the higher energy channels (8 μm Al and 12 μm Be) yielded a non-zero signal later in time and rose with the current for nearly 200 ns. These channels are sensitive to photons with energies greater than 1 keV. This may indicate that the plasma is heating and/or growing with time. We note that no early pulse of x-rays, such as those observed in exploding wires and laser initiated pinches, is observed.

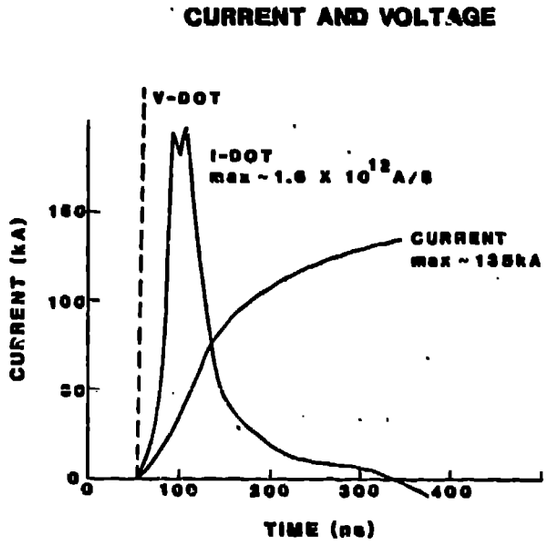

Fig. 3. Current and voltage measurements on 10 μm polyethylene capillary shot.

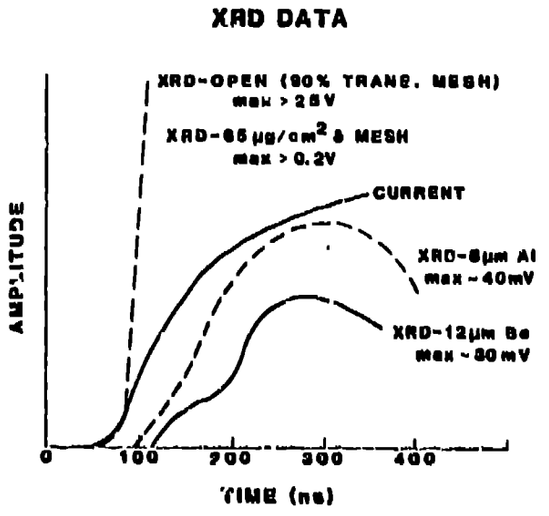

Fig. 4. X-ray data from 10 μm polyethylene capillary (same shot as Fig. 3). The soft x-ray channels (open and 65 μg/cm^2 formvar) quickly rise off scale while the hard x-ray channels (12 μm Be and 8 μm Al) which look at x-rays with energies greater than 1.0 keV rise for nearly 200 ns.

A test of a scribed capillary showed strong indications of preferential expansion along the split. A pinhole image was obtained on the shot through 7500 A of aluminum. A small plasma was produced with a diameter of ≈ 100 μm.

CONCLUSION

We have demonstrated that thin (10-25 μm diameter) capillaries can be fabricated in suitably configured insulators for use in pulse power machines. Large currents can be used to heat these capillaries which produce photons with an energies greater than 1 keV.

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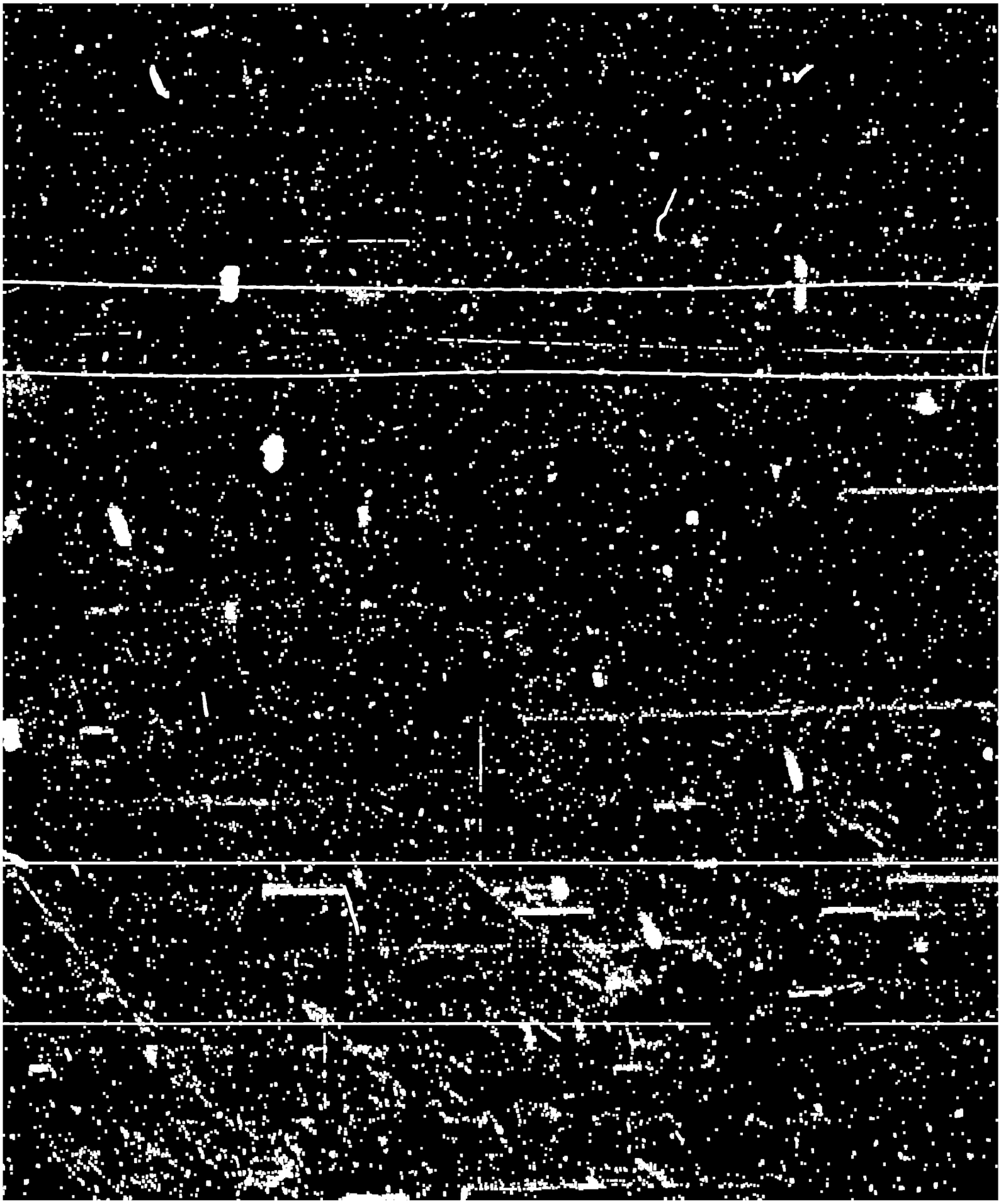
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