

# Wire Holder Geometry Effects in Z-Pinch Plasma Formation

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## **Abstract**

Low Current Pulser (LCP) experiments have shown that for some wire holder geometries, plasma expansion rates vary with electrode polarity. In this report I investigate the polarity dependence and present results from a parallel plate wire holder which suggest that this effect is a function of wire holder geometry.

## **1 Background**

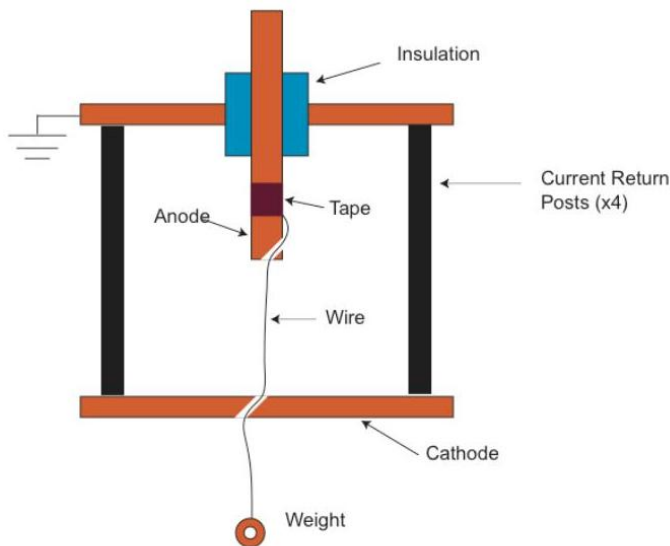
### **1.1 Cylindrical wire holder**

Over the last two years Peter Duselis used a wire holder with cylindrical symmetry for single wire z-pinch experiments. In these experiments a large current is driven through a wire in order to generate plasma. Consulting figure 1, we see this current is supported by the large potential drop across the anode-cathode gap. As discussed by Duselis, experimental results demonstrate that the system runs in a breakdown mode. That is, a large potential and low current condition is very rapidly replaced by a low potential, high current state following some breakdown or voltage collapse. We believe the breakdown mechanism is a Paschen avalanche, and that the high current conduction mode consists of free electrons flowing through a plasma shell surrounding the wire core.

### **1.2 Polarity Asymmetry**

Surprisingly, we found that breakdown mechanics are polarity dependent; choice of ground matters. For example, when the center post is an anode, soldering the cathode dramatically increases breakdown voltage. In contrast, when the center post is the cathode, soldering has little effect at all.

Figure 1: Basic Cylindrical Wire Holder Geometry Model



### 1.3 Proposed Mechanisms

One explanation for the asymmetry notes that electrons leave from the cathode, and will do so only when given a sharp surface, such as a post corner or unsoldered wire joint. In the case that the cathode is a post, soldering does not suppress electron emission as the post corners still provide good emission sites. In contrast, if the cathode is a plate, electron emission can be suppressed by soldering the cathode wire joint.

Another difference between using a positive and negative drive is the relative potential of the current return posts. Because the posts are held at ground, a radial  $\vec{E}$  field is produced between the posts and the wire. If, as in figure 2, the hot electrode is the anode, this field is directed outward. In addition, positive current will flow down (in the  $-z$  direction) and produce rings in the  $\vec{B}$  field as shown. The combination of the radial  $\vec{E}$  component and circular  $\vec{B}$  field will exert a downward force on charges in the anode-cathode gap. This inhibits electrons trying to cross the gap and delays breakdown.

If we flip the drive, such that the post side is positive,  $\vec{E}$  reverses direction. Because  $\vec{E}_z$  switches, so do both  $I$  and  $\vec{B}$ . The net effect is that  $\vec{E}_r \times \vec{B}$  continues to point downward. However, this now enhances the ability of electrons to enter the AK gap, and will lead to lower breakdown voltages.

Figure 2: Cylindrical Wire Holder Geometry Model with Grounded Cathode

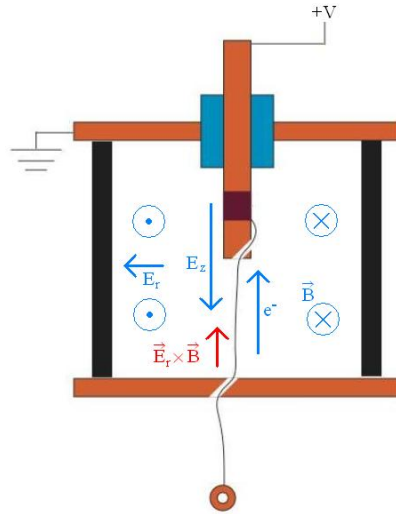
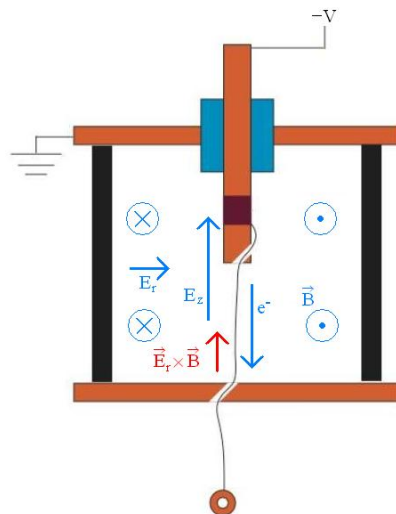


Figure 3: Cylindrical Wire Holder Geometry Model with Grounded Anode



		Cathode			
		No Solder No Tape	No Solder Tape	Solder No Tape	Solder Tape
Anode	No Solder No Tape	15.8, 15.7 15.9		11.8, 19.0 17.3, 17.0	15.2 16.8
	No Solder Tape				
	Solder No Tape	17.0 17.2		38.3, 51.0 37.5	43.1
	Solder Tape	16.2 17.6		38.9	52.3 36.1

Table 1: Breakdown voltage for various pulser configurations.

## 2 New Experiment

### 2.1 Physical Design

To determine if geometric asymmetry causes the polarity asymmetry, I built a parallel plate wire holder. This wire holder consists of two copper plates attached to a vacuum chamber flange. The outer plate rests on the flange near the O-ring groove, while the center plate is attached to the current feed-through. The center plate is nominally  $3'' \times 3''$ , and the outer plate is  $3\frac{5}{8}'' \times 3''$ . The two plate's top edges are aligned, as are two small holes which serve as wire guides. These holes are drilled as to center the wire on the small plate. We set a nominal 2.75 cm plate separation using mounting bolts.

### 2.2 Shot Configuration

We took shots in nine configurations. In any configuration an electrode is in one of three states: bare, soldered, or taped and soldered. In all cases we strung a wire through the guide hole in each plate. Hanging weight on the wire maintained mechanical and electrical contact for bare plates. Otherwise the wires were soldered to create a superior electric connection. We taped the edges of some plates with Kapton tape to suppress electron emission at the corners. In the future we will experiment with taped, unsoldered plates.

## 3 Results

Tables 1 and 2 summarize data collected so far. Two trends are obvious. First, soldering both sides increase breakdown voltage from a mean of 15.8 kv to a mean of 42.3kv. Secondly, taping edges does not have significant effect. We see a change of less than 4.5% when adding tape to a given configuration.

		Cathode			
		No Solder No Tape	No Solder Tape	Solder No Tape	Solder Tape
Anode	No Solder No Tape	15.8		16.3	16.0
	No Solder Tape				
	Solder No Tape	17.1		42.3	43.1
	Solder Tape	16.9		38.9	44.2

Table 2: Mean breakdown voltage for various pulser configurations.

## 4 Discussion

In cylindrical experiments with a negative drive, soldering had no effect on breakdown voltage. A dramatic increase in breakdown voltage is associated with soldering in experiments run with a positive drive. In the negatively driven parallel plate data, we see that soldering does effect breakdown voltage, which allows us to conclude that geometry differences caused the asymmetry in the original experiment. This conclusion is, of course, consistant with Maxwell's Equations which are invariant under changes of reference potential.

So far this data does not tell us whether  $\vec{E} \times \vec{B}$  drift or different wire mount point shapes are responsible for the observed asymmetry. In order to make this distinction, we can reverse the polarity of the parallel plate experiments. If postively driven parallel plate shots, yeild different breakdown voltages, we are likely observing  $\vec{E} \times \vec{B}$  drift effects. However, if reversing polarity in the parallel plate experiments does not impact breakdown voltage, we can conclude the asymmetry rests with the mount point geometry.