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FILAMENT PREHEATING FOR ϕ TARGETS

J. N. OLSEN

Sandia Laboratories

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J. N. Olsen
Sandia Laboratories
Albuquerque, New Mexico 87185

ABSTRACT

The vaporization and preheating of a CD_2 filament inside a target is examined to investigate operation of such a target. The experimental arrangement duplicated the previous shots, with prepulse levels of 40-120 kV and several μA , and use of identical ϕ targets with CD_2 filaments. The behavior of the filament was observed by optical methods and was seen to consist of luminous and plasma phases in turn. This behavior is consistent with earlier hypotheses concerning ϕ target operation.

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Introduction

Neutron production from relativistic electron beam-target interactions has been reported with " ϕ " targets.¹ In this concept a 3 mm plastic sphere is filled with a hot, magnetized plasma before the REB pulse begins to compress the target in an exploding pusher mode. The initial plasma is created by the explosion and heating of a 1 ml CD_2 filament internal to the target; the heating is driven by a large prepulse of voltage obtained by shorting out the prepulse suppressing switches on the accelerator. It is the purpose of this report to verify that the filament is indeed vaporized and heated by the prepulse.

Experimental Arrangement

These experiments were carried out on the same accelerator, Rehyd, as used for the neutron production tests. With the prepulse switches bypassed the machine prepulse voltage ranges from 40-120 kV during the 0.7 μsec Marx erection time as observed earlier. The magnitude of prepulse is roughly determined ($\pm 50\%$) by selection of main switch gas pressure and charge voltage. The target chamber, current monitors, and targets were those used previously.

The filament behavior during the prepulse time was observed in two modes, both utilizing a fast streak camera. In the simplest, luminosity of the filament and target walls was observed with a large aperture imaging system. The emission was so weak that 1:1 imaging was required and thus poor spatial resolution resulted; plans for spectroscopic analysis were abandoned. In the second scheme a large CW laser was used to obtain high resolution (10-20 μm) schlieren imaging of the filament. The optical system was similar to that used for gas discharge studies² except that a 12.5:1 image magnification was obtained.

Experimental Results

The behavior of the accelerator monitors is shown in Fig. 1 for a typical shot. This shot, #2190, was with a ϕ target cut away on one side for viewing access. Rehyd was charged to 75 kV with an A-K gap of 0.523". The Marx erection time, top signal, is 0.7 μ sec; a pick-off from this triggers the streak camera, as shown in the next trace, for a 0.5 μ sec streak. The integrated $\dot{V}$ and $\dot{B}$ signals for the machine prepulse are also shown. The traces are discontinued when the probes go off-scale at 0.48 and 0.64 μ sec respectively. A peak voltage of 64 kV was seen just before the current underwent a large increase to ≥ 10 kA. Presumably most of this current was collected by the thin aluminum disc on the top of the ϕ target.

Light emitted from the target is shown in Fig. 2 as obtained with the streak camera. The walls appear first at 0.34 μ sec followed at 0.58 μ sec by the filament. This latter time is close to the time of steep current increase. The timing of wall and filament flashing varied but the filament never preceeded the wall light. The current increase was always close to the filament starting time; however, no estimate of the filament/wall current ratio can be made from this data. The filament temperature may be estimated with a blackbody assumption using the instrumental sensitivity: $T \geq 0.35$ eV. There was the possibility in these results that the filament was not heated but was merely reflecting light emitted by the target walls. For this reason we turned to the schlieren technique.

A schlieren streak of the 1 mil filament is shown in Fig. 3 for shot #2200. In this shot the prepulse voltage peaked at 35 kV at 0.24 μ sec. The current underwent a characteristic steep increase at 0.38 μ sec to 5 kA at 0.45 μ sec; however, the filament did not start to expand until 0.50 μ sec. Observation of filament vaporization via the schlieren technique

always showed a 100-200 nsec lag from the time of current increase (in contrast, the luminosity measurements showed no time lag). The radial expansion velocity here is 2×10^5 cm/sec, the slowest of all those observed in the experiment. In this particular case the prepulse current stopped after 200 nsec when the prepulse voltage went through zero, with the result that the expansion stagnated. Vaporization of the target walls is evidenced in plasma coming in from the sides, a result expected from the luminosity measurements.

Discussion

These experiments suggest two phases in the filament preheating:

(a) Luminous phase. In the luminous phase the filament is emitting visible light but no plasma shows in the schlieren system. This phase begins with the steep increase in the prepulse current and is after the peak prepulse voltage (40-120 kV). After initiation, the voltage and current monitors ring off-scale with large amplitude oscillations.

(b) Plasma phase. With a 100-200 nsec delay after the increase of prepulse current (and beginning of luminous phase), a plasma forms around the CD_2 filament which is observable in the schlieren apparatus. The radial expansion velocity is in the range of $2-9 \times 10^5$ cm/sec.

The current carrying mechanisms during the two phases are probably different. At the beginning of the luminous phase an electric field of 100-200 kV/cm occurs between electrodes inside the target. This is sufficient for flashover³ along the CD_2 filament and/or field emission directly from the electrode. We assume then that the luminous phase is a flashover phenomenon. Appearance of a plasma is delayed by the length

of time required for flashover to heat the filament to the point of gas desorption, at which time avalanche ignition may occur. After creation of a surface plasma ohmic heating drives the plasma expansion observed in the schlieren data.

The data were further analyzed in an attempt to estimate temperatures and densities of the resultant plasma. During the luminous phase before plasma expansion a blackbody assumption yields $T \geq 0.35$ eV. Later during the schlieren-observed plasma phase, the expansion velocities were indicative of $0.2 \text{ eV} \leq T \leq 1.8 \text{ eV}$ for velocities of $2-9 \times 10^5$ cm/sec. This is consistent with $T \approx 1$ eV being required for ionization to produce an observable plasma. The question of whether the entire filament is heated or only desorbed surface gases is not answered here. The sensitivity of the schlieren system was good enough that either plasma would have been recorded, given reasonable gradient scale lengths.

The observations described in this report accomplish their stated purpose, that is, verification of filament vaporization and plasma formation during the Marx erection time. In addition, vaporization of the walls was observed, a less desired feature.

wall

 $t = 0.34 \mu s$

filament

$= 0.58 \mu s$ $= 0.78 \mu s$

← $t = 0.30 \mu s$

← $= 0.50 \mu s$

← $= 0.80 \mu s$

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