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SUMMARY AND CONCLUSIONS

Based on the above studies following conclusions were made.

a) It was shown that intense gigawatt relativistic electron beams can be generated in the presence of significant prepulse voltages in planar, annular and cylindrical diodes with a larger gap than that estimated by the space charge limited law. A maximum of 32% negative prepulse voltage has been recorded at the diode. Both the time duration and the amplitude of the positive prepulse voltage decrease with the increase in the Marx generator voltage. The highest positive prepulse voltage is 17% of the peak diode voltage. Electron beam generation mechanism in the presence of the prepulse has been analyzed by the expansion of the prepulse generated plasma and plasma filled diode. Increasing the AK gap reduces the prepulse voltage and eventually drops it below the explosive emission threshold and eliminates its creation. It was found that the positive prepulse voltage has no significant effect on the diode perveance and impedance. The effect of the prepulse is less pronounced in the cylindrical diode as compared to planar diode that allows one to operate the cylindrical diode with the AK gap ≤1.85 cm. Studies have been carried out to generate intense electron beam in the cylindrical electron beam diode when subjected to a high voltage bipolar pulse. In the positive voltage pulse, a copper mesh acts as a source of electrons. The diode perveance in the positive voltage pulse linearly increases with time due to the increase in the emission area. The electrode plasma closure is a small effect on the positive voltage pulse. During the negative voltage pulse, the diode impedance decreases with time due to the plasma expansion. Thus, even though there is a plasma formation on the anode during
the positive voltage pulse, the electron beam can be generated from the graphite cathode in the negative voltage pulse with a modest perveance ($\sim 1.1 \times 10^{-4} \text{ A/V}^{3/2}$).

b) It was found that for lesser AK gap there is shot to shot variation in the diode voltage and current for the same Marx generator voltage due to the nonreproducibility of the prepulse generated plasma. For perveance more than 200 $\mu$Perv we can consider the diode as short. The diode can be considered short if the Marx voltage/(Anode Cathode Gap)$^2$ is more than 56 kV/cm$^2$. Below 56 kV/cm$^2$ the effect of the prepulse will be less and the diode can be operated with a better shot to shot reproducibility. For the same Marx generator voltage, there is lot of shot to shot variation in the diode voltage and current in the annular cathode. Annular graphite cathodes of 40 and 70 mm diameters and 98 mm diameter planar graphite cathodes are not very suitable for reliable operation in the presence of prepulse. The effect of prepulse is more pronounced in the cathode of higher diameter due to a decrease in the uniformity of the prepulse generated plasma with the corresponding increase in the cathode diameter.

c) Intense relativistic electron beam has been generated in a planar diode with a dielectric cathode holder. It was found that for the Perspex length < 35 mm prepulse voltage appears at the diode either due to capacitive coupling or surface flashover at the Perspex insulator surface at the prepulse voltage itself. This surface flashover occurs at an unexceptionally low flashover fields could be because of the bipolar nature of the prepulse voltage. No prepulse voltage has been recorded at the diode for the Perspex length $\geq 35$ mm. But due to the pre breakdown time delay in the surface flashover across the insulator the rise time of the diode voltage increases. The diode current started rising after $\sim 50$ ns from beginning of the diode voltage, this reduces the
effective pulse width by 50 ns. Inserting a dielectric at the cathode holder could be a very effective method to reduce prepulse at the electron beam diode, but it increases the rise time of the diode voltage and reduces the effective electron beam pulse width.

d) In the case of the added inductance to the Blumlein circuit, the slower rise time reduces the prepulse voltage from 32% to ≤ 10%.

e) It was found that during the main pulse the diode impedance collapses due to plasma expansion from the cathode and anode surfaces. Electrode plasma expansion velocities are measured from the perveance data for planar and cylindrical graphite cathodes. For 31 mm AK gap planar diode the anode and cathode plasmas expand at 9.5 cm/μs toward each other. Plasma expansion velocity decreases for 25 mm AK gap. Electrode plasma expansion velocity has been measured when the planar diode is operated with a dielectric cathode holder to suppress prepulse. It was found that for 18-mm AK gap, the anode and cathode plasmas expand at 5.1 cm/μs toward each other. Plasma velocity increases with the current density. Plasma expansion velocity increases for 25-mm AK gap. Cylindrical electron beam diode perveance was measured for 1.85, 1.65, and 1.2 cm AK gaps. The anode and cathode plasma expansion velocities were measured using the perveance data. For 1.85 cm radial AK gap the anode and cathode plasmas expand at 5 cm/μs toward each other. Plasma expansion velocity decreases for 1.2 cm AK gap. The time dependence of the diode gap is calculated for cylindrical diode. It was found that in the initial stage of the 1.85 cm and 1.2 cm accelerating gap the plasma expansion velocity is very fast but after around 40 ns, the plasma expansion becomes relatively slow. In the case of 1.65 cm diode gap the plasma expansion velocity is very fast for the entire pulse duration. It was found that almost for all the cases, the plasma
expansion velocity increases with the AK gap. It may be possible that the higher electric field at lower AK gap is slowing one of the two electrode plasmas.

f) HPM has been generated from axial and coaxial virtual cathode oscillator using the IREB and the HPM power has been measured using a diode detector and receiving horn antenna set up. High power microwave has been detected by neon lamp discharge by HPM illumination when placed a few meter distances from the VIRCATOR window. A graphite explosive emission cathode has been used to generate intense electron beams. Microwave power has been optimized by changing the AK gap. It was found that the peak power occur around 6 mm anode cathode gap. The estimated microwave peak power \( \sim 1 \text{ kW} \) (within the effective aperture area of the receiving antenna) at 7 m distance from the VIRCATOR window. The corresponding peak power at the VIRCATOR window was 196 MW. It was observed that there was a shot to shot variation in the microwave peak power. HPM generation studies were carried out with a coaxial vircator using cylindrical electron beam diode in the presence of significant prepulse voltages. For 1.2 cm diode gap HPM has got more peak power as the diode detector was getting saturated even when the antenna has been placed at around 4.5 meter distance from the vircator output window. At this place the measured HPM peak power was more than 20 dBm (within the effective aperture area of the receiving antenna). The estimated peak power of the Coaxial Vircator was more than 1 MW.

Finally some suggested future work is being outlined.

a) Beam generation studies should be carried out with a gas prepulse switch.
b) Cathode and anode plasma expansion velocities should be measured more accurately with a streak camera.

c) Plasma expansion velocities should be measured for other cathode materials like velvet and carbon fiber and CsI coated cathodes.

d) HPM generation and measurements should be carried out with more accurate diagnostics.

Present work has contributed to a better understanding of intense gigawatt relativistic electron beam generation process and it’s usefulness towards HPM generation. The results of the study are useful in the design of a reliable and efficient large electron beam system and HPM devices.