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ANALYSIS OPTIMUM SPACE-CHARGE EFFECTS AND ENHANCED FREE-SPACE COUPLING FOR VIRCATOR DRIVEN BY COMPACT DRIVER

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Abstract

Our Research “Analysis Optimum Space-Charge Effects and Enhanced Free-Space Coupling for Vircator Driven by Compact Driver” is a findings shown, ultra-compact PT charges the solid dielectric PFL in 2s and 1s using RG218 cable and 450kV XLPE cable. In such small geometries, the voltage gains of PT are reached at 1:20. PFL, which are disclosed for the first time, are formed of coaxial cable to drive electron beam diodes in the form of vircators. It is stated that a tiny PFL charged by a new-configuration PT emits 1MW of microwave radiation between 4 and 8 GHz. With the aid of dry PFL and a repetition rate of 4Hz, the vircator is operated, and consistent performance in terms of frequency and peak power up to six consecutive shots is observed. In single shot mode of operation, shot to shot fluctuation is also demonstrated to be extremely minimal in terms of frequency and peak radiated power. When manufactured using high voltage XLPE cable in one case and RG218 cable in the other, the cable-based PFL pulsed power generator has electrical peak power delivery of 650 MW and 3.3 GW, respectively. After the vircator, a broadband conical horn antenna is constructed and put into use to optimize the radiation at the axis of the vircator. Also given are the findings of the antenna's 3D modeling. In-depth modeling of the outcomes in PIC code (XOOPIC two and half dimensional code) is also shown, along with the vircator efficiency of 0.3%, which is also stated. The vircator is said to be running at a 50kV A-K gap voltage, the lowest documented value for a vircator using a typical vircator shape. The current densities attained at this low anode cathode voltages are 300A/cm2, which is pretty near to the greatest values recorded in the literature, i.e. 450A/cm2. In two recorded occurrences, 500MW and 2GW of peak electrical power delivery capabilities using ultra-compact pulsed power generators employing bursting copper wire as the opening switch have been reported.

Key: Analysis, Optimum, Space-Charge, Effects, Enhanced, Free-Space, Coupling, Vircator Driven, Compact Driver.

INTRODUCTION

The input electrical powers necessary for the successful operation of these generators are in the range of GW, as demonstrated by several research teams striving to produce High Power

Microwaves using relatively larger pulsed power generators. As the impedances of such devices are often in the tens of s, this also calls for high voltages in the hundreds of kilovolts. The vircator is one of the most popular devices for producing microwaves due to its ease of manufacture and operation, tunability in radiation frequency by altering geometry, and simplicity of operation.

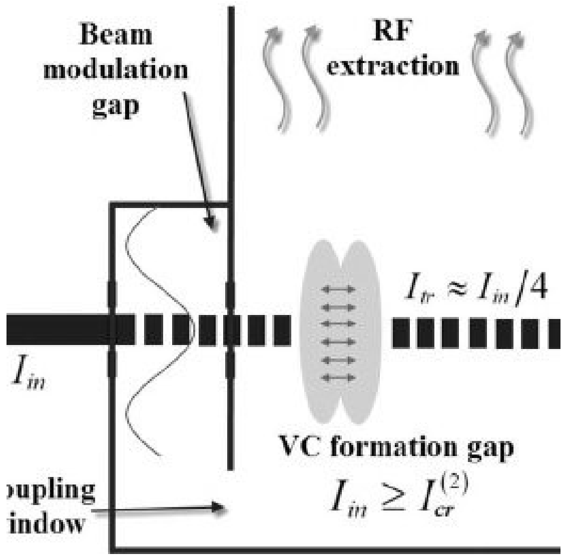

Fig.1: Analysis Optimum Space-Charge Effects and Enhanced Free-Space Coupling for Vircator Driven by Compact Driver Process.

Axial-vircators, which are among the easier to make vircator variations, have a low electrical to microwave power conversion efficiency. Regarding the conversion of electrical to microwave peak power, the efficiency of the vircator is not noticed rising by more than a few percent. The majority of generators used to power vircators are large, heavy machines that also need the operation of additional subsystems. They are difficult to transport outside of labs. Making the pulsed microwave generating system easier to use for experiments that need to be carried out outside of a lab environment is the goal of the work described in this thesis.

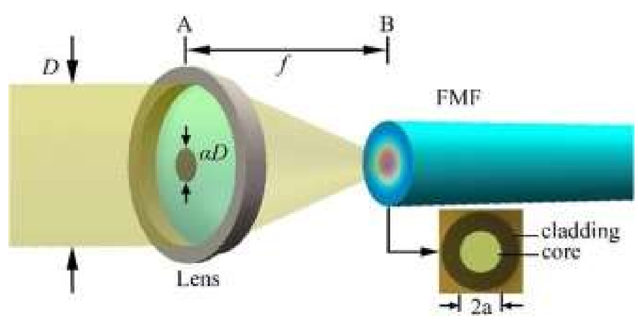

Fig.2: Analysis Optimum Space-Charge Effects and Enhanced Free-Space Coupling for Vircator Driven by Compact Driver Display

There have been various attempts to produce high power microwave sources using small pulsed power generators in the past, according to a literature review on the subject. The entire issue is effectively split into two ways. The first is the design and development of a compact pulsed power generator using any technique or plan for pulsed power compression or conditioning, which, of course, is based on the physics of energy storage (high energy density physics) and related dielectric breakdown in dielectrics. The second is the investigation of the optimized radiation from the vircator using the electrical powers supplied by these designed and developed compact pulsed power.

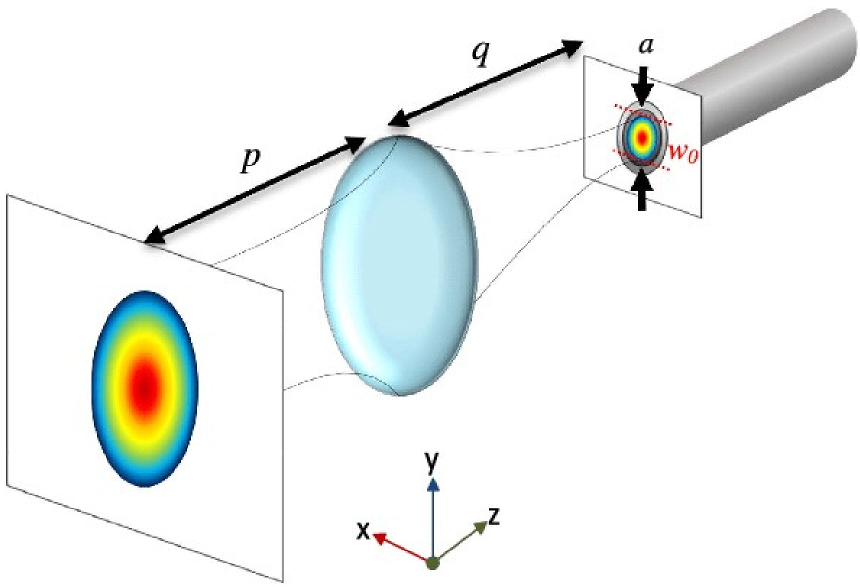

Fig.3: Analysis Optimum Space-Charge Effects and Enhanced Free-Space Coupling for Vircator Driven by Compact Driver Exp.

Despite seeming too straightforward to be taken into consideration, the first component has proved essential during the development or evolution phase. This has encouraged really excellent and intriguing work to be done and led to papers that also deal with the creation of tiny pulsed power sources for HPM applications. Even if the development phase is a sort of vertical or one-dimensional research of the subject, it would not have been feasible without taking some pertinent applied physics principles into consideration. High power pulsed microwaves are used for microwave plasma interactions in addition to their interference effects in electronic equipment [4].

Survey

Coaxial cables are frequently made using solid dielectrics. Polyethylene (PE) is the dielectric that cables utilize most frequently. PE insulated cables are nearly maintenance-free, lighter, and offer less thermal resistance for a given voltage and conductor cross section as compared to oil paper or mass impregnated cable [14]. The cables have undergone a number of beneficial modifications, particularly in their high voltage withstand capacities, thanks to advancements in PE in the form of HDPE (high density poly ethylene), LDPE (low density poly ethylene), and cross linked polyethylene (XLPE).

The availability of these cables and the ongoing technological advancement in the field of cable technology point to the possibility of using ready-made cables for creating a pulse forming line in order to eventually build a compact pulsed power source that requires no-maintenance during the operational life of the pulsed power source. High voltage transmission using XLPE coaxial cables has made its way up to 500kV. Advanced generators, transformers, and pulsed power sources have all been developed using XLPE cables [5, 9, 53, 61]. Both the impulse breakdown superposed on AC voltage [6] and the breakdown of XLPE under DC voltage have been examined. Steiner has researched and reported on the occurrence of partial discharges in low voltage wires.

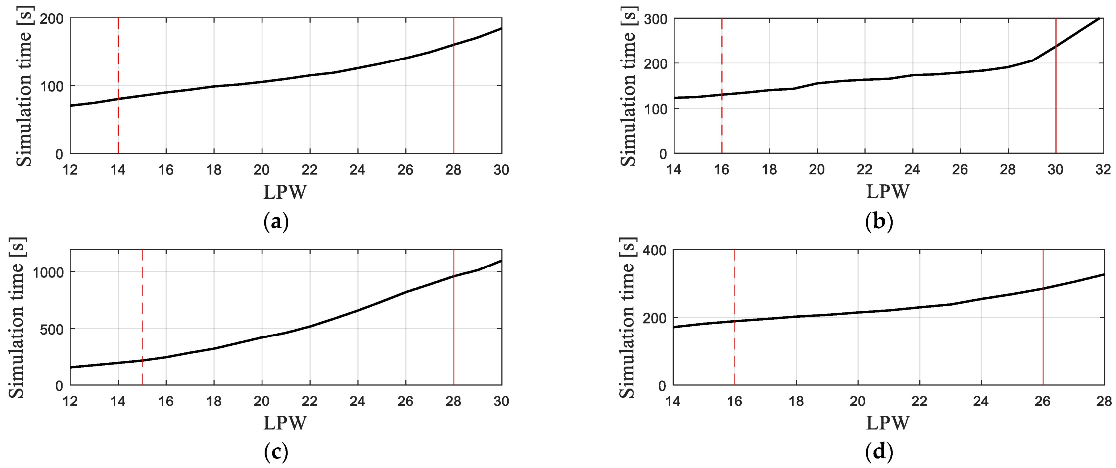

Fig.4: Analysis Optimum Space-Charge Effects and Enhanced Free-Space Coupling for Vircator Driven by Compact Driver Graph.

Riechert et al. [12–14] conducted a thorough analysis of the coaxial XLPE cable with regard to breakdown that occurs under DC pre-stress as well as under unipolar and bipolar impulses. These findings imply that the cable's impulse breakdown strength is less than it would be at the same DC voltage. According to the explanation, as a homopolar space charge forms around the inner conductor at high DC voltage, the field strength within the cable's insulator weakens, increasing the dielectric strength of the cable.

Diode voltage measurement

We utilized another high-bandwidth probe that we created in-house to monitor the voltage applied between the anode and cathode of the virtual cathode oscillator. In actuality, this is a cascade of two voltage probes. The input of the second voltage divider, which is commercially available and operates at a comparatively lower voltage, receives the output of the first high voltage divider. A CuS O4 liquid resistor column was used to create this high bandwidth high voltage divider.

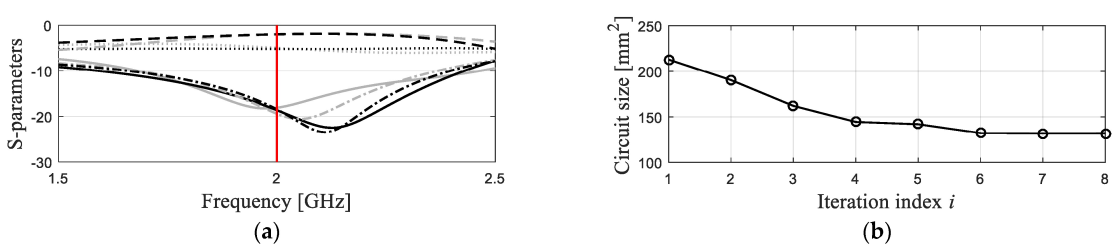

Fig.5: Analysis Optimum Space-Charge Effects and Enhanced Free-Space Coupling for Vircator Driven by Compact Driver.
This was done to rule out the possibility that attenuation ratios may change over time due to variations in the concentration of the liquid resistor, as the ratio would not change if both arms had the same resistivity all the time. It was created in a manner consistent with that described in the reference [46]. Depicts the resistive divider, depicts the first stage resistive divider's reaction to an applied rapid voltage pulse. The divider's rise time, which is roughly 7 ns, may be utilized to measure the anode cathode gap voltage. The lower arm of the 40 cm total liquid column is sampled from electrodes within a liquid resistor that are situated at a distance of 1 cm.

Another resistive and high bandwidth voltage divider with a 1000:1 attenuation, 20 kV DC voltage, 40 kV peak voltage, and 75 MHz bandwidth (Tektronics make 6015A) is used with the main high voltage divider's lower arm, which is already made of a liquid resistor column, to further attenuate the voltage to a level where we can safely send the signal to the oscilloscope. The 40 cm long liquid resistor column of the first high voltage probe allows for greater voltage measurements, which contributes to its significance.

Current Measurement

The pulse transformer's primary discharge current was measured in the first series of trials. It was accomplished by creating a self-integrating Rogowski coil that adheres to the L-R integration theory. a self-integrating Rogowski coil calibration curve. The self-integrating current transformer created in the lab is calibrated using a current transformer made by M/S Pearson.

Electron Beam Impression

A thermal paper was utilized in the beginning, or in the initial set of tests, to determine the electron beam profile. This paper became blackened as a result of the heating caused by the bombardment of electron beams. It is in the way of the released electrons since it is placed before the anode mesh. Later, it was discovered that the SS mesh employed as the experiment's cathode also bears the mark of electron beam bombardment.

Results

Additionally, single capacitor bank powered devices are quite huge, heavy, and need a significant amount of starting energy. Due to the slowness of single capacitor banks, they use numerous lines for optimal current interruption, which may not be particularly practical. Since the current rise rate is 70 Amp/ns, the current density is 1x1012 Amp/m 2, and the peak power is dissipated into the wire, this small generator can also be used to generate high pressure, low density metal plasma, which is in the same range as was previously used for experiments [140].

The ultra-compact Marx generator was created to directly drive a reflex triode vircator at high repetition rates, but despite the device's differences, the present technology is likened to it [141]. The current generator is modelled at 18.5 load impedance and found to provide 200kV of load voltages, which is equal to 2GW of load power and is the same as that of the tiny Marx generator previously described. In other words, the Marx generator produces almost the same voltage and powers as those reported in the current experiment if modeled for a load of 10.5. The current system is equivalent to the system that was previously published in terms of size, although it weighs far less than a tiny Marx-based generator.

However, in order to maintain high pressure S F6 and air/nitrogen inside the Marx generating vessel, additional sub-systems are needed. The Marx based system (37kg weight stated for [141]) may be employed in the repeated mode. When compared to the cost of 80 to 100 capacitors used in the tiny Marx generator, the cost of all 12 capacitors used in the already disclosed system is just 40 USD, making this feature no less appealing.

Conclusion

For two sets of tests, a small pulse transformer is created, tested, and developed to have the appropriate coupling coefficients between the primary and secondary based on the coaxial cable base PFL characteristics.A very innovative design process was used to create the transformers, in which the primary capacitor bank assumes the form of a primary turn of a pulse transformer. With such a pulse transformer's design, a voltage gain ratio of up to 1:20 has been reached between the primary and secondary.

The transformer is incredibly small and employs air as insulation rather than adding more weight to protect PFL from secondary voltages up to 250kV. The pulse transformer's design and outcomes are supported by the intricate 3D modeling of such a pulse transformer.

explains the diagnostics used in the research described in this thesis in brief. By the conclusion of this chapter, it should be clear that many high voltage probes may be connected in series to increase the measuring voltage range and that their bandwidth can be measured experimentally using short yet rapid pulses.

In order to create a small pulsed power generator controlling vircator, a totally dry type PFL is intended to be employed in the experiment. Pulsed forming lines based on RG218 cable have been created and utilized in the first two sets of tests described in chapter 6. The PFL is created utilizing a high voltage device with a 450kV rating in the third and final series of trials.

Since their primary capacitor bank is formed like a primary turn, the pulse transformers for the second and third sets of trials are both small and innovative in their construction.

A compact pulse transformer is conceived, built, and tested for the voltage gains of 1:20 in the described configuration of primary and secondary capacitance for the second set of trials. It has a 160 kV secondary voltage rating while operating in the air, and additional efforts to improve the insulation on the PFL's output switch have resulted in a peak charging of 200 kV for the PFL or secondary capacitor. The primary winding of the transformer has a single turn, making it extremely small (6kg in weight) and innovative in its construction.

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