COMPACT FLASH X-RAY UNITS

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Abstract

Flash x-ray units are used to diagnose pulsed power driven experiments on the Pegasus machine at Los Alamos. Several unique designs of Marx powered flash x-ray units have been developed to meet the requirements of the Pegasus experiments. All of these units are compact, battery powered, fiber optically controlled, and EMP shielded. Some of these units are operated with a windowless x-ray tube in the Pegasus machine vacuum tank thereby making the full bremsstrahlung spectrum available for both hard and soft x-ray images. Other units obtain multiple x-ray flashes that are almost collinear by employing an x-ray tube configuration which allows closely spaced x-ray emitting anodes. These units all emit a 10 ns FWHM x-ray pulse. Their Marx banks store from 12 to 100 Joules of electrical energy. The x-ray output ranges from 20 to 100 mR at .3 m with endpoint energies from 100 to 500 KeV.

Introduction

The Pegasus machine is often used to implode a thin aluminum liner onto experimental packages. Flash x-rays are used to diagnose the liner implosion and sometimes the reaction of the experimental package. The flash x-ray units must be able to withstand the EMP environment and meet the operating constraints of Pegasus. The compact single unit construction makes EMP shielding them easier as well as making them more convenient to use. The operating constraints of the Pegasus machine require battery power and fiber optic control. The Pegasus machine has 3 sets of ports perpendicular to the axis of the implosion so up to 3 radial flash x-rays can be taken on each shot without resorting to multiple exposure units. A typical radial flash x-ray unit will be described in detail.

A Typical Radial Flash X-Ray Unit

These units are built around a 12 stage, 12 Joule, 360 kV Marx bank which was derived from an 8 stage spark-gap-trigger Marx[1] which is still available commercially[2]. The unique feature of this Marx design is its 1 ns risetime which is obtained because they are built with a high stage to ground capacitance compared to the stage to stage capacitance. This insures that the Marx erects sequentially since the stage to ground capacitance prevents subsequent stages from seeing voltage until the presently firing stage is fully turned on. As the Marx erects, energy is stored in the stage to ground capacitance of each stage, and each stage in effect pulse charges the next. When the output stage fires it discharges the energy stored in the stage to ground capacitance of the last stage directly into the output. Since this last stage has been pulse charged in a similar 1 ns time period the output gap will hold off enough voltage for its stage to ground capacitance to become fully charged. These factors allow this Marx design to have such a short risetime to full voltage with a measured output impedance around 45 ohms.

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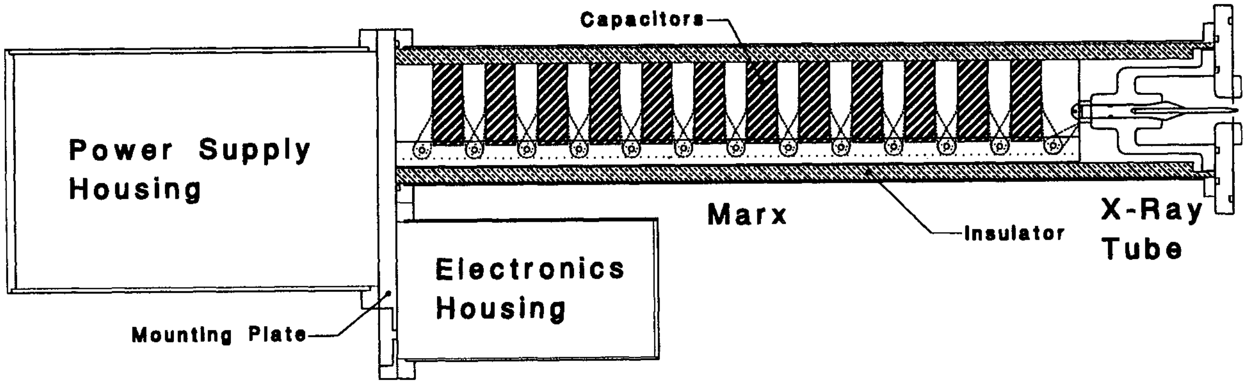

Figure 1. Side view of a complete radial flash x-ray unit showing the relative placement of the components.

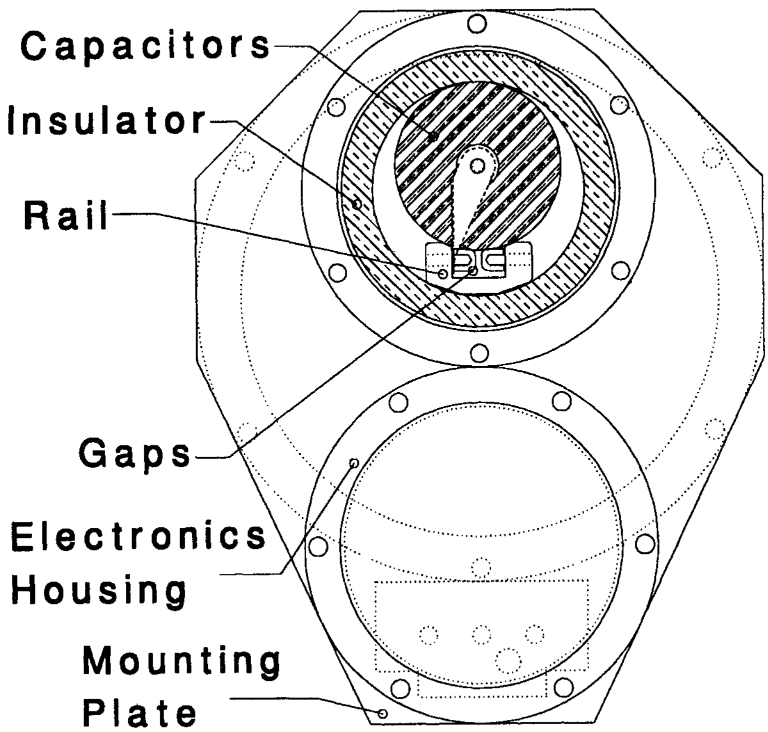

Figure 2. End view of a radial flash x-ray unit showing the Marx and mounting plate details.

Figures 1 & 2 show the layout of these units. All the housings are aluminum cans which have been Alodined[3] to prevent oxide formation which would cause poor joint contact and reduce EMP shielding. The Marx bank is contained in a sealed can which is pressurized to 90 psi with dry air for spark gap operation and to reduce corona which would promote pretriggering. Because the pulse durations are only a few tens of nanoseconds the pressurized air also insulates the connection to the x-ray tube without high voltage breakdown. The capacitors are 2.7 nF 30KV TDK ceramic doorknobs. Half mm thick brass straps mount the capacitors to the polycarbonate rail which holds the spark gaps. The Marx rail assembly fits tightly inside a nylon tube for support. The nylon tube is in turn a slip fit in the aluminum Marx tube. The Marx is charged by means of 2 watt carbon composition resistors in the Megohm impedance range. These resistors hold up well for Marx designs with one capacitor per stage, but start to fail when more capacitors are used in each stage. The power supply and trigger unit are contained in a separate non-pressurized can which is isolated by line filters from the can containing the sensitive electronics and batteries. A Gamma High Voltage Research[4] RC-10 series power supply changes the 28 Vdc input to an adjustable regulated 30 kVdc output to charge the Marx. The trigger unit uses a Krytron tube to discharge a .1 uF 3 kV capacitor into a step up transformer whose 35 kV output pulse is applied to a Trigatron type gap in the first stage of the Marx. The fiber optic control consists of a fiber to turn on and charge the unit which is backed up by a separate key plug which must be inserted to operate the unit. Another fiber sends back a signal to indicate that the unit has reached full charge, while a third fiber fires the Marx bank trigger unit. The electronic controllers contain the safety links to the room entry doors and they activate the x-ray warning lights.

The X-Ray Tube

The radial units employ a windowless x-ray tube design which uses the vacuum inside the Pegasus tank as shown in Figure 3.

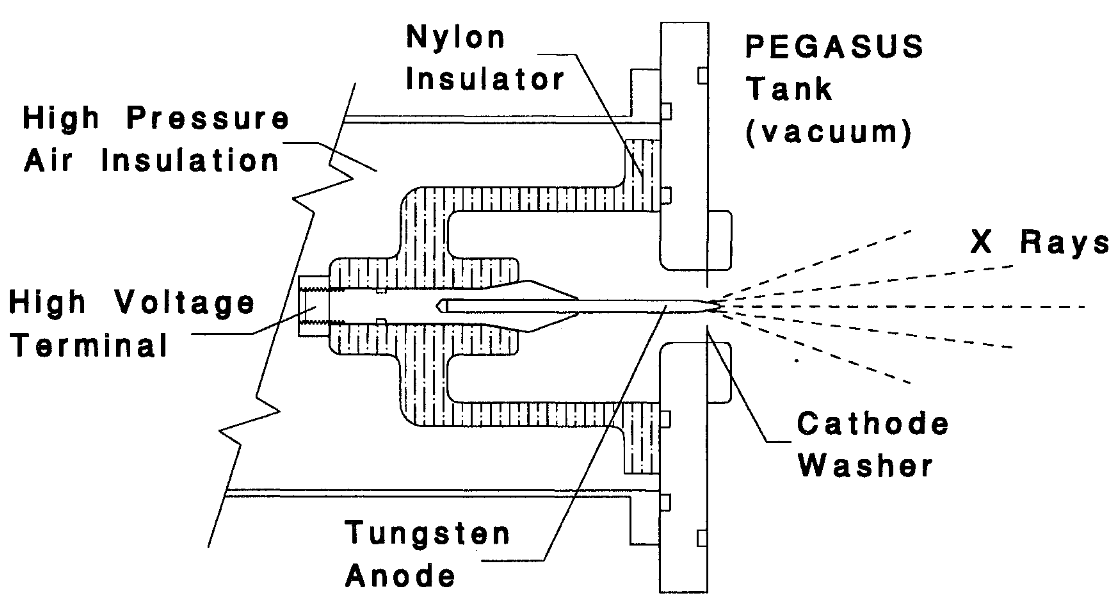

Figure 3. The flash x-ray tube showing the windowless design which emits the full x-ray spectrum.

The Marx pulses the anode to a high positive potential which starts electron emission from the cathode. The x-ray pulse ends when the Marx runs out of energy or the anode cathode gap is closed by plasma. The x-ray tube uses a .1 mm-metal washer as a cathode. More cathode washers somewhat spaced out and smaller holes lower the tube impedance. A matched impedance will give the best power transfer however more x-ray output may be obtained with somewhat higher tube voltages since the x-ray fluence is approximately proportional to the third power of the voltage on the tube. The anode is most often a tungsten rod, but other materials can be used to obtain different x-ray spectral distributions. The anode rods used range in diameter from several mm to sub mm. The smaller anodes produce less x-rays, but the images are sharper due to the smaller source sizes. The tube is easily modified so these tradeoffs can be determined experimentally by optimizing image quality. The x-ray pulse is normally about 10 ns FWHM, but changes in the tube configuration can modify this. If pulse length is critical it should be monitored when experimenting with tube configuration.To obtain a high contrast image of the thin aluminum liner and other small, low density objects it helps to use soft x-rays in the 5 - 30 keV range. Commercial sealed x-ray tubes use a thin stainless steel or kovar window to contain the vacuum. This window attenuates the spectrum below about 50 keV. Soft x-ray tubes use beryllium windows; however, this is not a material which one would want scattered around the inside of the vacuum chamber where one has to work to set up the next shot. The windowless tube design allows all the low energy x-rays that are produced by the tungsten target to be emitted. The spectrum is quite strong below 10 keV because of Tungsten L radiation and increased target transparency to continuous bremsstrahlung below the L adsorption edge. At the upper end of the energy range the film response is dropping off rapidly at 30 keV so the harder x-rays contribute very little to the image. Behind the soft x-ray films hard x-ray images are also obtained by using films with fluorescent converter screens.

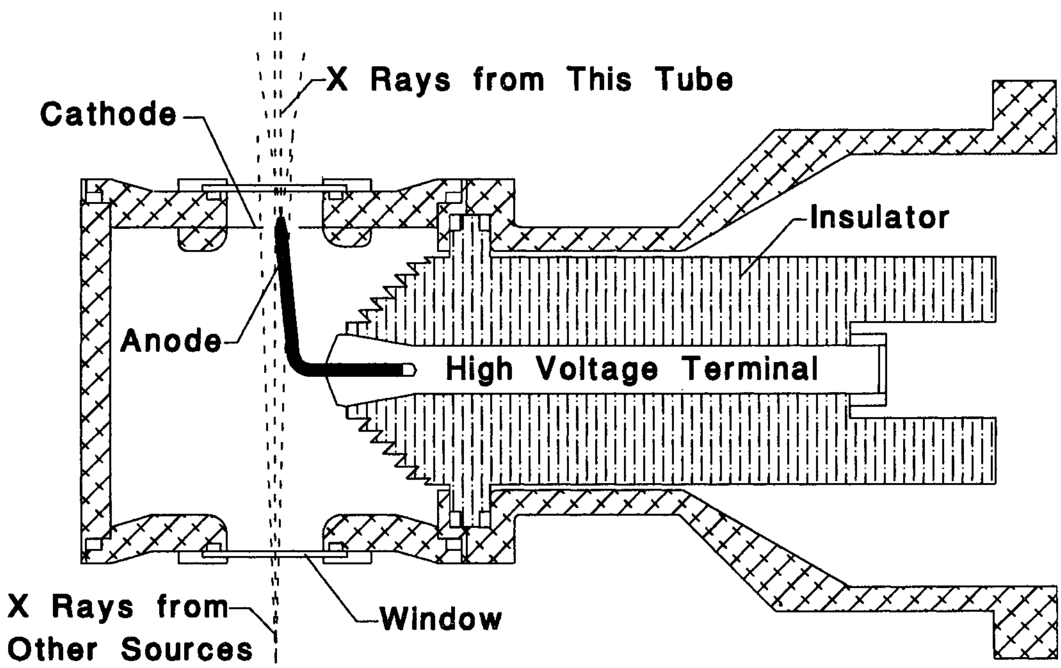

Figure 4. Transparent x-ray tube.

Axial X-Ray Units

The axial x-ray units are larger versions of the radials since they must often penetrate considerable protection plus two mm of copper in the glide planes. When imaging the liner the path through the aluminum is about 2 cm so it can be imaged with the hard x-rays that will penetrate the copper. A 15 stage, 90 Joule, 600 kV x-ray unit is commonly used on axis. This unit is built using the same general principles as the radials, but it uses 3 capacitors per stage. In some cases it is desirable to have multiple frames taken along approximately the same axial line of sight. This is accomplished by stacking several transparent(to x-rays) x-ray tubes along the axis. Figure 4 shows such a tube. Each x-ray tube has an independent Marx. The images are then recorded by multiple gated cameras imaging a fluor.

Conclusion

These compact flash x-ray units have been reliable and convenient to use. They are inexpensive to build, and would be useful in diagnosing other experiments.

References

1. D. Platts, Proceedings of the Third IEEE International Pulsed Power Conference, Albuquerque, NM, 1981, p.485.

2. Veradyne Corp., 330 N. Victory Blvd., Burbank, CA 91502, (213) 849-6003.

3. Alodine is a conversion coating for aluminum by Parker Achem, Madison Hgts., MI.

4. Gamma High Voltage Research, Ormond Beach, FL 32174, (904) 677-7070.