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Switched Power Workshop: Power Supply Working Group

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SWITCHED POWER WORKSHOP:
POWER SUPPLY WORKING GROUP

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SUMMARY

The power supply working group was assigned the problem of pulse charging the 3-MeV gun. The gun is a radial line structure that has two charging configurations: a single ring charged to 500 kV or nine rings charged from 100 to 200 kV. In either configuration, the pulsed source must rapidly charge the structure's ring(s) before breakdown can begin.

The issues encountered in charging the structure can be divided into two categories. First, the charging system must be well matched to the gun structure. Proper impedance matching will avoid reflections and limit the fault current if the ring should spark. Second, several systems can achieve the wide range of charge voltages necessary. Some are better suited to high voltages, while others are better at low voltages.

The following paragraphs will address the impedance matching issues and review three choices for pulse generators. A system for each type of source is described along with a very rough cost estimate.

GUN STRUCTURE MATCHING

The gun structure with the most stringent load requirements is the single-ring configuration charged to 500 kV. The structure appears as a 15.6-pF capacitive load when charged uniformly. However, the structure

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appears as a pair of transmission lines when viewed from any single point. Table 1 lists the load parameters of the single ring structure, and Fig. 1 illustrates a transmission line model of the ring structure when viewed from a single point.

It is easy to imagine charging the ring with a set of flexible cables that contact the ring at equally spaced intervals. Yet each charge point launches waves traveling in opposite directions; these waves interfere with other waves from adjacent charging points. The result is a charged ring with some overriding mode structure that can lead to locally high electric fields.

Table 1. Dimensions and load parameters for the single ring structure.

Mechanical	
Disk spacing	2 mm
Disk radius	30 cm
Average ring circumference	1.88 m
Ring width	0.3 mm
Ring area	565×10^{-6} m^2
Ring spacing to cathode disk	1.6 mm
Electrical	
Charge voltage (peak)	500 kV
Charge voltage rise time	2 ns
Ring capacitance to cathode disk	3.13 pF
Ring capacitance to anode disk	12.5 pF
Total capacitance[a]	15.6 pF
Total stored energy	1.96 J

a Total capacitance calculation neglects fringe fields and ring thickness.

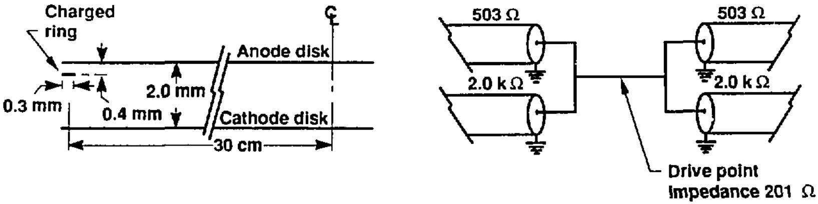


Figure 1. (a) Cross section of the gun structure showing a 0.3 mm ring suspended between two 60 cm diameter disks. (b) Schematic illustration of the ring's impedance as seen from a single point. The ring appears as a dual-strip transmission line extending in two directions.

A better charging scheme would avoid potential differences around the ring by making the gun structure part of a coaxial transmission line as shown in Fig. 2. The transmission line is 30 or 40 Ω and is terminated to avoid reflections. The capacitance of the ring is in parallel with the resistance of the terminator. The transmission line becomes a rugged, integral part of the gun structure, vacuum system, and laser trigger optics. The short transit time provided by the line serves to

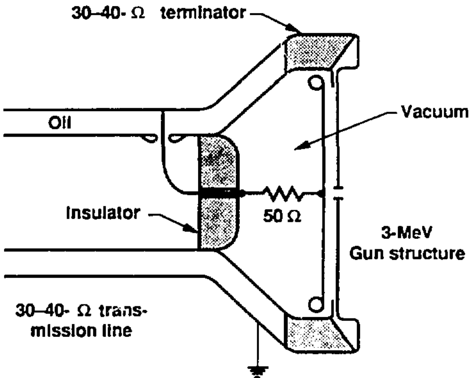
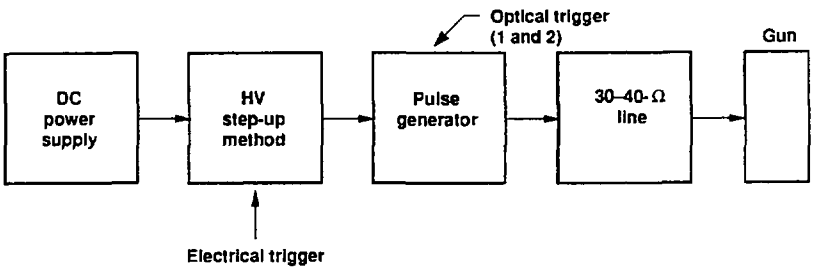


Figure 2. An outgrageously oversimplified sketch of an oil-filled transmission line joining the gun structure

prevent adverse gun behavior from impacting the source. Now the problems center on generating a charging pulse at the input of the transmission line.

SELECTION OF A PULSE GENERATOR

The pulse generator must produce the desired peak charge voltage in a pulse that rises in 2 ns and that has a duration of approximately 6 ns. The pulse generator must also be well synchronized with the laser pulse that triggers the gun structure. A variety of pulsed network configuration applies, and each favors a range of charge voltage. Figure 3 illustrates the general pulse generator and lists three networks that



	Generator type	Voltage range	Switching
1.	Oil-filled Blumlein	~500 kV	Laser-triggered spark gap
2.	Charged line	~200 kV	Photoconductive switch
3.	Nonlinear compressor	~100 kV	Saturating magnetic or dielectric devices

Figure 3. Block diagram of the pulsed system with a list of three possible generators.

could pulse the transmission line at three voltage levels. For example, the single ring charged to 500 kV is best serviced by an oil-filled Blumlein generator initiated by a laser-triggered spark gap. The high voltage step-up block in Fig. 3 identifies a method to charge the generator. This can be accomplished by several common methods, such as a Marx bank or a thyratron-switched, high voltage transformer. A schematic diagram of each generator style is shown in Fig. 4 with connections to the voltage step-up block and gun transmission line.

COST ESTIMATES

Table 2 below lists rough costs of designing and fabricating any one of the three systems identified in Figs. 3 and 4. The costs do not include gun design and fabrication efforts, facilities preparation, computer time, travel, or consultants.

Table 2. Cost estimates for a pulsed source.

LABOR CATEGORIES	[MAN-MONTHS]
Physics staff	12
Engineering	15
Design	10
Tech Support	24
Administration	5
TOTAL LABOR	66 M-Mo
COST SUMMARY	[K$]
Total labor (10k$/M-Mo)	660
Fabrication (8M-Mo @ 22 day/mo @ $75/hr)	106
Supplies	75
Equipment:	
Power Supply	25
Optics	25
Diagnostics	50
TOTAL COSTS	941 k$

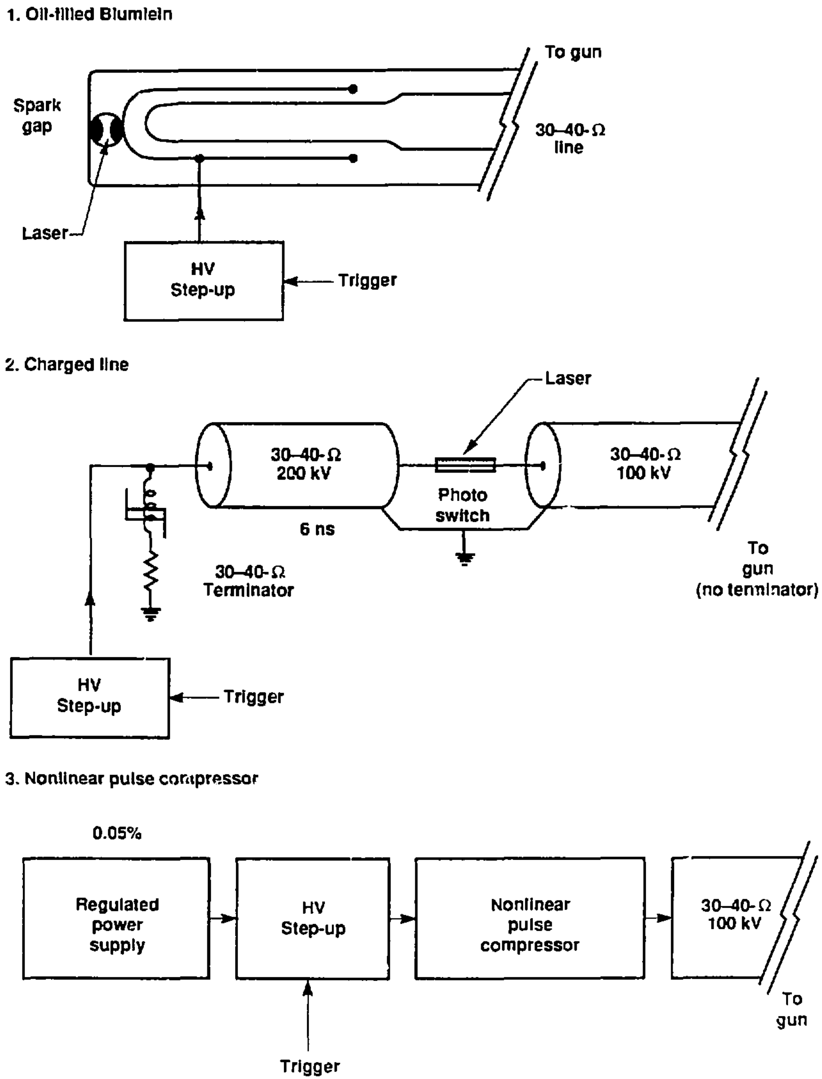


Figure 4. Block diagrams of three possible generator styles.

CONCLUSIONS

We have found that the method of pulse generation is less of a problem than interfacing the generator to the ring structure. The interface must combine the issues of ring suspension, vacuum, optics and proper pulse termination into a single compact structure. Once the gun structure is connected to a transmission line, a variety of pulse generators can provide the required pulse shape and amplitude.

The pulse generators reviewed are categorized by voltage as shown in Fig. 3. The high and mid-voltage generators both use laser-triggered switches to produce a pulse. The laser-triggering schemes are attractive because they can be well synchronized with the photocathode illumination. The low voltage generator uses saturating magnetics or dielectrics[1] as a pulse compression method. This scheme is also attractive because the network is reliable, requires little maintenance, and will operate at a high pulse repetition frequency.

REFERENCE

1. H. Ikezi, "Compression of a Single Electromagnetic Pulse in a Spatially Modulated Nonlinear Dielectric," J. Appl Phys. 64 (6), (1988), p. 3273